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A MANUAL OF ZOOLOGY

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A
MANUAL OF ZOOLOGY

BY

T. JEFFREY PARKER, D.Sc., F.R.S.
PROFESSOR OF BIOLOGY IN THE UNIVERSITY OF OTAGO,
DUNEDIN, N. Z.

AND

WILLIAM A. HASWELL, M.A., D.Sc., F.R.S.
PROFESSOR OF BIOLOGY IN THE UNIVERSITY OF SYDNEY, N.S.W.

*REVISED AND ADAPTED FOR THE USE OF AMERICAN
SCHOOLS AND COLLEGES*

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PREFACE

In planning the present work the aim of the authors has been to provide a manual embodying a course of study adapted to the requirements of the student chiefly in higher classes of schools, and to some extent in junior classes of universities. To make this, within the necessarily narrow limits of space imposed, anything more than a bare synopsis, it has been necessary to restrict the extent of the ground covered. This has been done (1) by leaving out altogether certain classes of existing animals; (2) by omitting all descriptions of extinct groups; (3) by dealing only very briefly with embryology. Opinions must differ as to the best selection of groups for an elementary manual of this kind. But broadly, there can, it has appeared to us, be little doubt that what should be omitted, or only briefly dealt with, are the groups of rare occurrence and uncertain relationships, the greater part of the space being devoted to the more familiar representatives of the large phyla.

A course of laboratory and museum instruction, supplemented by work in the field and on the seashore, is absolutely necessary in order that any sound knowledge of zoology may be attained. The present manual does not provide such instruction, but is intended to be used in association with it, and the examples selected for description are such as may under most circumstances be readily obtained.

The general plan is similar to that followed in the *Text-Book of Zoology* by the same authors, but the restricted space has necessitated considerable modifications. We have not adopted the method, followed in various recent manuals, of beginning with one of the larger Invertebrata or with a vertebrate, and working from that upwards and downwards. The reasons given for such a mode of treatment we understand to be that if we begin with the simplest animals, the Protozoa, we discourage and embarrass the beginner by introducing him at once into a world entirely new to him, requiring him at the same time to learn the use of an entirely unfamiliar instrument the microscope. But in our opinion, the difficulty is much less than is alleged by the advocates of the alternative method, and the advantage of presenting the facts at the outset in a natural and logical order by far outweigh any such disadvantages. We are convinced that any general acquaintance which the student may possess beforehand with a rabbit or a crayfish will be of little real value to him when he begins to take up seriously the study of its structure. Moreover an elementary knowledge of the use of the microscope is absolutely essential to any adequate study of Zoology as an intellectual discipline, and this difficulty, such as it is, may as well be met first as last.

Owing to the lamented death of Professor T. Jeffrey Parker, at a time when but little progress had been made with this work, his actual share in it has been but slight: but as it was planned between us, and the earlier parts had the advantage of his revision, and more especially as it owes a great deal to his work in the *Text-Book* it has been thought right to let it appear under our joint names as originally intended.

I have to express very great indebtedness to Professor W. Newton Parker for the pains he has taken in revising the proof-sheets and for many valuable suggestions which he has made during the progress of the work.

WILLIAM A. HASWELL.

PREFACE TO THE AMERICAN EDITION

This American edition of Parker and Haswell's useful and concise "Manual of Zoology" has been adapted for the use of American schools. Common American forms closely similar to the European or Australasian ones described in the English edition, have been mentioned, so that the student can use the book in examining the allied typical forms from his own country. In the majority of cases the European species differ only in trivial characteristics, so that one general description will answer for both.

In a very few cases the American editor has revised and corrected views or statements not believed to be correct. For example, few, if any, American zoologists would regard Limulus as an undoubted Arachnidan.

A few additional American animals have been referred to and figured, while a few cuts not reproduced in the English edition have been copied from Parker and Haswell's "Text-book of Zoology," and also from Sedgwick's "Text-book of Zoology."

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MANUAL OF ZOOLOGY

INTRODUCTION

Zoology, the branch of Natural History which deals with animals, is one of the two subdivisions of the great science of **Biology,** which takes cognizance of all *organisms,* or things having life, as distinguished from such lifeless natural objects as rocks and minerals. The second of the two subdivisions of Biology is **Botany,** which deals with plants.

The subject-matter of Zoology, then, is furnished by the animals which inhabit the land-surface, the air, and the salt and fresh waters of the globe; the aim of the science is to find out all that can be known of these animals, their structure, their habits, their mutual relationships, their origin.

The first step in the study of Zoology is the recognition of the obvious fact that the innumerable individual animals known to us may be grouped into what are called **species,** the members of which resemble one another so closely that to know one is to know all. The following example may serve to give the reader a fairly accurate notion of what zoologists understand by species, and of the method of naming species which has been in use since the time of the great Swedish naturalist Linnæus.

The domestic cat, the European wild cat, the ocelot, the leopard, the tiger, and the lion are animals which agree with one another in the general features of their organisation—in the number and form of their bones and teeth, in the possession of retractile claws, and in the position and characters of their internal organs. No one can fail to see that these animals, in spite of differences of size, colour, markings, etc., are all, in the broad sense of the word, "cats." This is expressed in the language of systematic Zoology by saying that they are so many **species** of a single **genus**.

According to the system of *binomial nomenclature* introduced by Linnæus, each kind of animal receives two names—one the *generic name*, common to all species of the genus; the other the *specific name*, peculiar to the species in question. Both generic and specific names are Latin in form, and are commonly Latin or Greek in origin, although frequently modern names of persons or places, with Latinised terminations, are employed. In giving the name of an animal, the generic name is always placed first, and is written with a capital letter, the specific name following it, and being written, as a rule, with a small letter. For instance, to take the examples already referred to, the domestic cat is called *Felis domestica*, the European wild cat *F. catus*, the leopard *F. pardus*, the tiger *F. tigris*, the lion *F. leo*. Thus the systematic name of an animal is something more than a mere appellation, since it indicates the affinity of the species with other members of the same genus: to name an animal is, in fact, to classify it.

It is a matter of common observation that no two individuals of a species are ever exactly alike: two tabby cats, for instance, however they may resemble one another in the general characters of their colour and markings, invariably present differences in detail by which they can be readily distinguished. *Individual variations* of this kind are of universal occurrence. Moreover, it often happens that the members of a species are divisible into groups distinguishable by fairly constant characters: among domestic cats, for instance, we find white, black, tabby, gray, and tortoiseshell cats, besides the large long-haired Persian breed, and the tailless Manx cat. All these are distinguished as *varieties* of the single species, *Felis domestica*.

It is often difficult to decide whether two kinds of animals should be considered as distinct species or as varieties of a single species, and no universal rule can be given for determining this point. Among the higher animals mutual fertility is a fair practical test, the varieties of a species usually breeding freely with one another and producing fertile offspring, while distinct species either do not breed together or produce infertile *hybrids* or mules. Compare, for instance, the fertile mongrels produced by the union of the various breeds of domestic dog with the infertile mule produced by the union of the horse and ass. But this rule is not without exception, and in the case of wild animals is, more often than not, impossible of application: failing it, the only criterion of a "good species" is usually the presence of constant differences from allied species. Suppose, for instance, that a naturalist receives for description a number of skins of wild cats, and finds, after an accurate examination, that in some specimens the tail is two-thirds the length of the body and the skin of a uniform reddish tint with a few markings on the head, while in the rest the tail is nearly half as long as the body and the skin tawny with black stripes. If there are no intermediate gradations between these two sets of individuals, they will be placed without hesitation in distinct species: if, on the other hand, there is a complete series of gradations between them, they will be considered to form a single variable species.

As, therefore, animals have to be distinguished from one another largely by structural characters, it is evident that the foundations of a scientific Zoology must be laid in **Morphology**, the branch of science which deals with form and structure. Morphology may be said to begin with an accurate examination of the external characters; the divisions of the body, the number and position of the limbs, the characters of the skin, the positions and relations of the mouth, eyes, ears, and other important structures. Next the internal structure has to be studied, the precise form, position, etc., of the various organs, such as brain, heart, and stomach being made out: this branch of morphology is distinguished as **Anatomy**. And, lastly, the various parts must be examined by the aid of the microscope, and their minute structure, or **Histology**, accurately determined. It is only when we have a fairly comprehensive knowledge of these three aspects of a given animal — its external characters, its rough anatomy, and its histology — that we can with some degree of safety assign it to its proper position among its fellows.

An accurate knowledge of the structure of an animal in its adult condition is not, however, all-sufficient. Nothing has been made more abundantly clear by the researches of the last half-century than that the results of anatomy and histology must be checked, and if necessary corrected, by **Embryology** — *i.e.* by the study of the changes undergone by animals in their development from the egg to the adult condition. A striking instance is afforded by the common barnacles which grow in great numbers on ships' bottoms, piers, etc. The older zoologists, such as Linnæus, grouped these creatures, along with snails, mussels, and the like, in the group Mollusca, and even the great anatomical skill of Cuvier failed to show their true position, which was made out only when Vaughan Thompson, about fifty years ago, proved, from a study of the newly hatched young, that their proper place is among the Crustacea, in company with crabs, shrimps, and water-fleas.

Given a sound knowledge of the anatomy, histology, and embryology of animals, their **Classification** may be attempted — that is, we may proceed to arrange them in groups and sub-groups, each capable of accurate definition.

The general method of classification employed by zoologists is that introduced by Linnæus, and may be illustrated by reference to the group of cats which we have already used in the explanation of the terms genus, species, and variety.

We have seen that the various kinds of true cat — domestic cat, lion, tiger, etc. — together constitute the genus *Felis*. Now there is one member of the cat-tribe, the cheetah, or hunting leopard, which differs from all its allies in having imperfectly retractile claws and certain peculiarities in its teeth. It is therefore placed in a distinct genus, *Cynælurus*, to mark the fact that the differences separating it from any species of Felis are of a more fundamental character than those separating the species of Felis from one another.

The nearest allies of the cats are the hyænas, but the presence of additional teeth and non-retractile claws — to mention only two points — makes the interval between hyænas and the two genera of cats far greater than that between Felis and Cynælurus. The varying degree of difference is expressed in classification by placing the hyænas in a separate **family**, the *Hyænidæ*, while Felis and Cynælurus are placed together in the family *Felidæ.* Similarly the civets and mongooses form the family *Viverridæ;* the dogs, wolves, jackals, foxes, etc., the family *Canidæ;* bears, the family *Ursidæ;* and so on.

All the foregoing animals have sharp teeth adapted to a flesh diet, and their toes are armed with claws. They therefore differ fundamentally from such animals as sheep, deer, pigs, and horses, which have flat teeth adapted for grinding vegetable food, and hoofed feet. The differences here are obviously far greater than those between any two of the families mentioned above, and are emphasised by placing the flesh-eater in the **order** *Carnivora,* the hoofed animals in the order *Ungulata.* In the same way gnawing animals, such as rats, mice, and beavers, form the order *Rodentia;* pouched animals, such as kangaroos and opossums, the order *Marsupialia;* and so on.

Carnivora, Ungulata, Rodentia, Marsupialia, etc., although differing from one another in many important respects, agree in the possession of a hairy skin and in the fact that they all suckle their young. They thus differ from birds, which have a covering of feathers, and hatch their young from eggs. The differences here are considerably more important than those between the orders of quadrupeds referred to, and are expressed by placing the latter in the **class** *Mammalia,* while birds constitute the class *Aves.* In the same way the scaly, cold-blooded lizards, snakes, tortoises, etc., form the class *Reptilia;* the slimy-skinned, scaleless frogs, toads, and salamanders the class *Amphibia;* and the finned, water-breathing fishes the class *Pisces.*

Mammals, birds, reptiles, amphibians, and fishes all agree with one another in the possession of red blood and an internal skeleton — an important part of which is the backbone or vertebral column — and in never having more than two pairs of limbs. They thus differ in some of the most fundamental features of their organisation from such animals as crabs, insects, scorpions, and centipedes, which have colourless blood, a jointed external skeleton, and numerous limbs. These differences — far greater than those between classes — are expressed by placing the backboned animals in the **phylum** or **sub-kingdom** *Chordata*, the many-legged armoured forms in the phylum *Arthropoda.* Similarly, soft-bodied animals with shells, such as oysters and snails, form the phylum *Mollusca,* polypes and jellyfishes the phylum *Cœlenterata.* And, finally, the various phyla recognised by zoologists together constitute the **kingdom** *Animalia.*

Thus the animal kingdom is divided into phyla, the phyla into classes, the classes into orders, the orders into families, the families into genera, and the genera into species, while the species themselves are assemblages of individual animals agreeing with one another in certain constant characters. It will be seen that the *individual* is the only term in the series which has a real existence: all the others are mere groups formed, more or less arbitrarily, by man.

To return to the animal originally selected as an example, it will be seen that the zoological position of the domestic cat is expressed as follows: —

Kingdom — ANIMALIA.
  Phylum — CHORDATA.
    Class — MAMMALIA.
      Order — CARNIVORA.
        Family — *Felidæ.*
          Genus — *Felis.*
            Species — *F. domestica.*

The object of systematic zoologists has always been to find a *natural* as opposed to an *artificial* classification of animals. Good instances of artificial classification are the grouping of bats with birds on the ground that both possess wings, and of whales with fishes on the ground that they both possess fins and live in the water. An equally good example of a natural classification is the grouping of both bats and whales under the head of Mammalia because of their agreement, in all essential points of anatomy, histology, and embryology, with the hairy quadrupeds which form the bulk of that class.

With the older zoologists the difficulty was to find some general principle to guide them in their arrangement of animals — some true criterion of classification. It was believed by all but a few advanced thinkers that the individuals of each species of animal were descended from a common ancestor, but that the original progenitor of each species was totally unconnected with that of every other, having, as Buffon puts it, "participated in the grace of a distinct act of creation." To take an instance: all wolves were allowed to be descended from a pair of ancestral wolves, and all jackals from a pair of ancestral jackals, but the original pair in each case was supposed to have come into being by a supernatural process of which no explanation could or ought to be offered. Nevertheless it was obvious that a jackal was far more like a wolf than either of them was like a tiger, and that in a natural system of classification this fact should be expressed by placing the wolf and jackal in one family, the tiger in another.

All through the animal kingdom the same thing occurs: no matter what group we take, we find the species composing it resemble one another in varying degrees, or, as it is sometimes expressed, have varying degrees of *relationship* to one another. On the view that each species was separately created, the word relationship was used in a purely metaphorical sense, as there could, of course, be no real relationship between two groups of animals having a totally independent origin. But it was assumed that creation had taken place according to a certain scheme in the Divine Mind, and that the various species had their place in this scheme like the bits of glass in a mosaic. The problem of classification was thus to discover the place of each species in the pattern of the unknown design.

The point of view underwent a complete change when, after the publication of Darwin's *Origin of Species* in 1859 the **Doctrine of Descent** or of **Organic Evolution** came to be generally accepted by biologists. A species is now looked upon, not as an independent creation, but as having been derived by a natural process of descent from some pre-existing species, just as the various breeds of Domestic Fowl are descended from the little jungle-fowl of India. On this view the resemblances between species referred to above are actually matters of relationship, and species are truly allied to one another in varying degrees, since they are descended from a common ancestor. Thus a natural classification becomes a genealogical tree, and the problem of classification is the tracing of its branches.

This, however, is a matter of extreme difficulty. Representing by a tree the whole of the animals which have ever lived on the earth, those existing at the present day would be figured by the topmost twigs, the trunk and main branches representing extinct forms. Thus the task of arranging animals according to their relationships would be an almost hopeless one but from two circumstances: one, that remains of many extinct forms have been preserved: the other, that the series of changes undergone by an animal in its development from the egg often forms an epitome of the changes by which, in the course of ages, it has been evolved from an ancestral type. Evidence furnished by the last-named circumstance is, of course, furnished by embryology: the study of extinct animals constitutes a special branch of morphology to which the name **Palæontology** is applied.

The solid crust of the earth is composed of various kinds of rocks divisible into two groups: (1) *Igneous rocks*, such as granite and basalt, the structure of which is due to the action of the internal heat of the globe, and which originate below the surface and are not arranged in layers or strata; (2) *Aqueous* or *sedimentary rocks*, which arise by the disintegration, at the surface of the earth, of pre-existing rocks, the fragments or débris being carried off by streams and rivers and deposited at the bottom of lakes or seas. Being formed in this way by the deposition of successive layers or strata, the sedimentary rocks have a *stratified* structure, the lowest being in every case older than the more superficial layers. The researches of geologists have shown that there is a general *order of succession* of stratified rocks; that they may be divided into three great *groups*, each representing an *era* of time of immense but unknown duration, and that each group may be subdivided into more or fewer *systems* of rocks, each representing a lesser *period* of time.

Imbedded in these rocks are found the remains of various extinct animals in the form of what are called *fossils*. In the more recent rocks the resemblance of these to the hard parts of existing animals is perfectly clear; we find shells hardly differing from those we pick up on the beach, bones easily recognisable as those of mammals, birds, or fishes, and so on. But in the older rocks the fossils are in many cases so different in character from the animals existing at the present day as to be referable to no existing order. We find birds with teeth, great aquatic reptiles as large as whales, fishes, molluscs, Crustacea, etc., all of an entirely different type from any now existing. We thus find that the former were in many cases utterly unlike the present animal inhabitants of the globe, and we arrive at the notion of a *succession of life in time*, and are even able, in exceptionally favourable circumstances, to trace back existing forms to their extinct ancestors.

By combining the results of comparative morphology, embryology, and palæontology we get a department of Zoology called **Phylogeny**, the object of which is to trace the pedigrees of the various groups. There are, however, very few cases in which this can be done with any approach to exactness; most "phylogenies" are purely hypothetical, and merely represent the views at which a particular zoologist has arrived after a more or less exhaustive study of the group under discussion.

Animals may also be studied from the point of view of **Distribution.** One aspect of this study is inseparable from Palæontology, since it is obviously necessary to mention in connection with a fossil the particular system or systems of rocks in which it occurs: thus we distinguish **geological distribution** or **distribution in time.**

The distribution of recent forms may be studied under two aspects, their **horizontal** or **geographical distribution,** and their **vertical** or **bathymetrical distribution.** To mention the latter first, we find that some species exist only on plains, others — hence called *alpine forms* — on the higher mountains; that some marine shells, fishes, etc., always keep near the shore (*littoral* species), others live at great depths (*abyssal* species), while others (*pelagic* species) swim on the surface of the ocean. Among aquatic animals, moreover, whether marine or fresh-water, three principal modes of life are to be distinguished. There are animals such as jelly-fishes, which float on or near the surface of the water, and are carried about passively by currents; such forms are included under the term *Plankton*. Most fishes, whales, and cuttle-fishes, on the other hand, are strong swimmers, and are able to traverse the water at will in any direction; they together constitute the *Nekton*. Finally, such animals as crabs, oysters, sponges, zoophytes, etc., remain permanently fixed to or creep over the surface of the bottom, and are grouped together as the *Benthos*.

Under the head of geographical distribution we have such facts as the absence of all land-mammals, except bats in New Zealand and the Polynesian Islands, the presence of pouched Mammals, such as kangaroos and opossums, only in some parts of America and in Australia and the adjacent islands, the entire absence of finches in Australasia, and so on. We find, in fact, that the *fauna* — *i.e.* the total animal inhabitants — of a country is to a large extent independent of climate, and that the faunæ of adjacent countries often differ widely. In fact, it is convenient in studying the geographical distribution of animals largely to ignore the ordinary division into continents, and to divide the land-surface of the globe into what are called *zoo-geographical* regions.

There are still two departments of zoological science to be mentioned. As it is impossible to have a right understanding of a machine without knowing something of the purpose it is intended to serve, so the morphological study of an animal is imperfect without some knowledge of its **Physiology**, *i.e.* of the functions performed by its various parts, and the way in which they work together for the welfare of the whole.

Not only may we study the action of a given animal's organs, but also the actions of the animal as a whole, its habits, its relations to other animals, whether as friends, as enemies, or as prey, to the vegetable kingdom, and to its physical surroundings, such as temperature, humidity, etc. In a word, the whole question of the relation of the *organism* to its *environment* gives us a final and most important branch of Natural History which has been called **Ethology** or **Bionomics.**

SECTION I.—PHYLUM PROTOZOA

1. THE RHIZOPODA

The simplest members of the animal kingdom are for the most part, too small to be visible without the aid of a microscope, or at least so small as to appear to the unassisted eye as extremely minute specks, not distinguishable, unless in unusually active movement, from small particles of non-living matter. Representatives of this class of simple minute animals are to be found living under a variety of different conditions; they are abundant in fresh water, running or stagnant, and they are equally numerous in the sea, while they are also to be found living in the fluids of cavities in the bodies of higher animals. An example which will serve to illustrate some of the main features of the class is the Proteus animalcule or **Amœba**. Amœba (Fig. 1) is sometimes to be found by searching with the aid of the microscope in water from stagnant pools. To the unpractised beginner it is a difficult task to discriminate between the microscopic particles of non-living matter which form the main part of the sediment at the bottom of such a pool—débris of animals, vegetable or mineral nature—and the object of which he is in search. Numerous minute bodies will doubtless be seen which their active movements among the motionless particles show to be endowed with life. But

Amœba is not one of these. It is to be recognised as a glassy-looking, irregularly shaped particle with a definite outline. From a particle of some crystalline mineral substance, to which such a description would equally well apply, Amœba would soon be distinguishable owing to the circumstance that it is constantly changing its shape.

This change is effected by the pushing out of projections or processes, called *pseudopods* or *pseudopodia* (*psd*), which undergo various alterations of size and shape, and may become withdrawn, other similar processes being developed in their place. At the same time careful watching shows that the Amœba is also, with extreme slowness, changing its *position*. This it effects by a kind of streaming motion. A projection forms itself on one side, and the entire substance of the Amœba gradually streams into it; a fresh projection appears towards the same side, the streaming movement is repeated, and, by a constant succession of such movements, an extremely gradual locomotion, which it often takes very close watching to detect, is brought about. In these movements, it is to be noticed, the Amœba is influenced

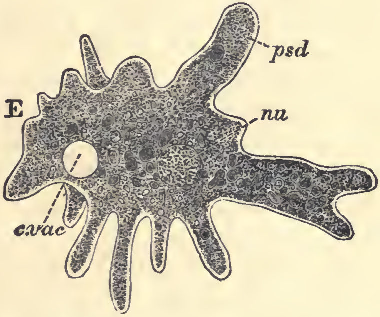


FIG. 1.—**Amœba proteus**, a living specimen. *c. vac*, contractile vacuole, *nu*, nucleus; *psd*, pseudopods. (From Parker's *Biology*, after Gruber.)

to some extent by contact with other minute objects; when the processes come in contact with small grains of sand or other similar particles, their movements are modified in such a way that the Amœba, in its slow progress onwards, passes on one side of them, so that it might be said to feel its way among the solid particles in a drop of sediment.

Judging from the nature of the movements, we are obliged to infer that the substance of which this remarkable object is composed must be soft and semi-fluid, yet not miscible with the water, and, therefore, preserving a sharp contour. These and other characteristics to be mentioned subsequently enable us to conclude that we have to do with the substance of complex chemical composition termed *protoplasm*, which constitutes the vital material of all living organisms whether animals or plants. In Amœba the protoplasm is clearly distinguishable into two parts, an outer homogeneous, glassy-looking layer completely enclosing a more granular internal mass.

Examination of the Amœba with a fairly high power of the microscope reveals the presence in its interior of two objects which with a low power we should be likely to overlook. One of these is a small rounded body of a homogeneous appearance, which preserves its form during all the changes which the Amœba as a whole undergoes. This is termed the *nucleus* (Fig. 1, *nu*); it is enclosed in an extremely delicate membrane, and consists of a protoplasmic material differing from that which forms the main bulk of the Amœba in containing a substance which refracts the light more strongly and which has a stronger affinity for certain colouring matters. The other minute object to be distinguished in the interior appears as a clear rounded space (*c. vac*) in the protoplasm. When this is watched it will be observed to increase gradually in size till it reaches a maximum of, let us say, a fifth of the total diameter of the Amœba, when by a sudden contraction of its walls, it suddenly disappears, to reappear presently and gradually grow again to its maximum size. This pulsating clear space is the *contractile vacuole.*

By watching the Amœba carefully for some time we may be enabled to observe that the movements of the protoplasm of the body not only effect locomotion, but are connected also with the reception of certain foreign particles of organic nature — *i.e.*, either entire minute animals or plants, or minute fragments of larger forms — which form the *food* of the Amœba, — into the interior of the protoplasm. A process of the protoplasm is pressed against such a particle of food, which becomes sunk in the soft substance, and passes gradually into the interior. Here it becomes surrounded by a little globule of watery fluid, and by degrees partially or wholly disappears; the part, if any, which remains, subsequently passes outwards from the protoplasm into the surrounding water. The matter which disappears evidently mixes with the protoplasm and adds to its bulk.

When food is abundant the Amœba increases in bulk — more food being ingested than is required for simply maintaining the size unaltered — and soon a remarkable change takes place. The processes become withdrawn, and a fissure appears dividing the Amœba into two parts (Fig. 2). This fissure grows inwards, and the two parts become more and more completely separated from one another, till eventually the separation becomes complete, and we have two distinct Amœbæ resulting from the division of the one. While the protoplasm has been undergoing this division into two halves the nucleus also divides, and each of the two new Amœbæ possesses a nucleus similar to the original one, and developed from it by division. It is mainly by this simple process of division into two, or *binary fission*, as it is called, that reproduction or multiplication takes place in the Amœba.

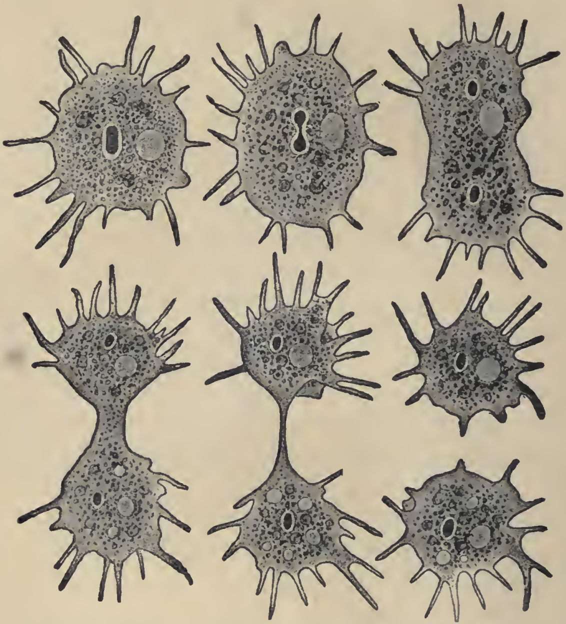


FIG. 2.—**Amœba polypodia** in successive phases of division. The light spot is the contractile vacuole; the dark the nucleus. (From Lang's *Text-Book*, after F. E. Schulze.)

Amœba thus consists of an undivided particle of protoplasm containing a nucleus. To such a particle the term *cell* is applied. In higher groups the animal when fully developed, consists of a number of such cells, usually differing in character in different parts; and simple animals, such as Amœba, in which the entire animal consists throughout life of a single cell, are distinguished as *unicellular* from the *multicellular* form in which a number of cells are combined. The whole of the great group or *phylum* of animals — the *Protozoa* — to which Amœba belongs, are distinguished from all the remaining groups of the animal kingdom — the *Metazoa* — by their unicellular character.

Among the Protozoa a large number resemble Amœba in the possession of pseudopodia or processes of the protoplasm. The pseudopodia-bearing Protozoa constitute one of the great divisions or *classes* into which the Protozoa are divided by zoologists — the class known as the **Rhizopoda**. In only a comparatively small proportion of the members of this class have the pseudopodia the comparatively short and blunt shape which they have in Amœba. All the Rhizopoda with comparatively short and thick pseudopodia are grouped together to form one of the leading divisions or *orders* of Rhizopoda — the order **Lobosa**. Amœba is one of the simplest of these. The largest among the near relatives of Amœba is *Pelomyxa*, which may be as much as 8 mm. in diameter, so that it is readily visible to the naked eye; its pseudopodia are very short and broad, and, instead of a single nucleus, it contains a large number as well as many contractile vacuoles. Other Lobosa differ from Amœba in the presence of a shell or *test* enclosing the protoplasm. One of these is *Difflugia* (Fig. 3, *D*), which is very common in fresh water. Difflugia has a flask-shaped test formed of agglutinated sand-grains and other foreign particles. The main bulk of the protoplasm is contained in the interior of the shell, but comparatively long pseudopodia are capable of being pushed out through the mouth of the flask. It pierces the wall of the cells of Spirogyra, inserts its pseudopods, lifting the entire cell-contents out and passing them into its body within the shell (Stokes). An even commoner member of the group is *Arcella* (Fig. 3, *C*). Arcella has a shell much wider than that of Difflugia, convex on one side, flat on the other. In the middle of the flat surface is a rounded opening. The shell of Arcella is of a transparent, tough material, which is said to be *chitinoid* from the fact that it appears to resemble a substance termed *chitin*, of a horny consistency, very general in its occurrence in the integument of animals. This chitinoid test exhibits a minute pattern when examined under a high power of the microscope.

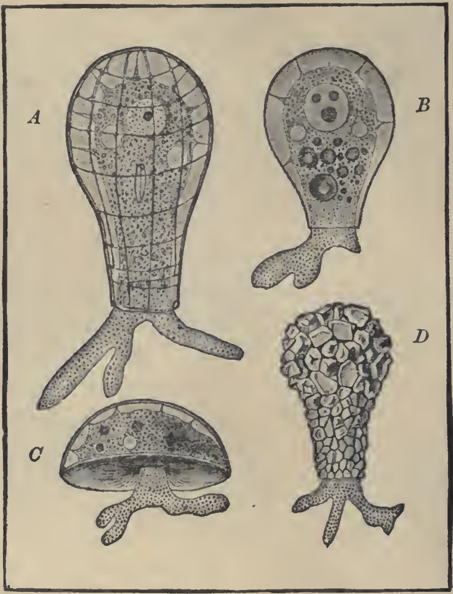
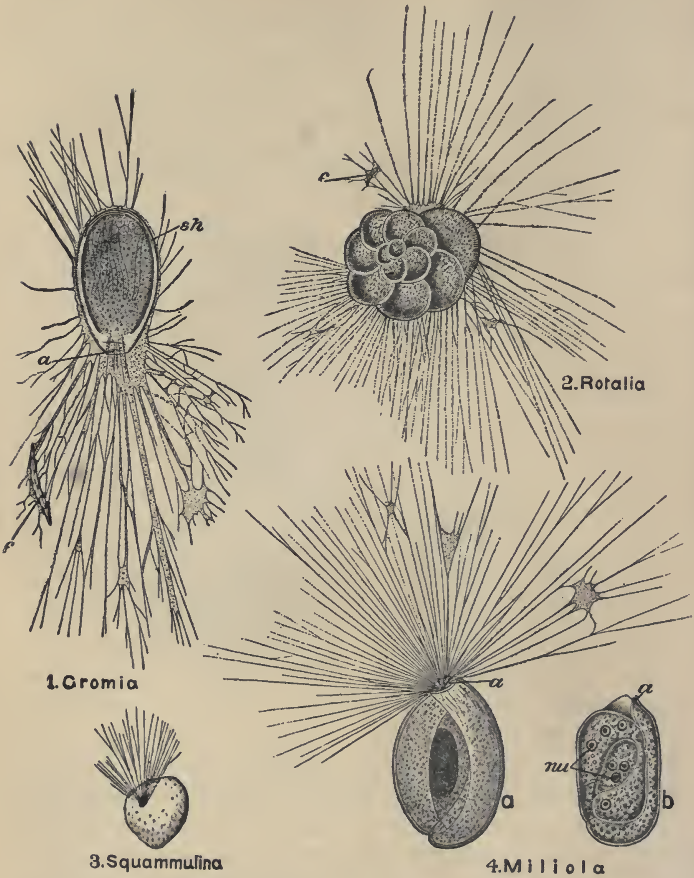


FIG. 3.—A, **Quadrula symmetrica**; B, **Hyalosphenia lata**; C, **Arcella vulgaris**; D, **Difflugia pyriformis**. (From Lang's *Comparative Anatomy*, after Schulze and Wallich.)

The bulk of the protoplasm is, as in Difflugia, enclosed within the test, but a considerable portion of it may be pushed out in the form of pseudopods. Several nuclei and a contractile vacuole are contained in the protoplasm. The body of the animal is colourless, and is attached to its test, says Stokes, "by fine threads of its own substance." There are several species in our fresh-water pools, among them *Arcella vulgaris* (Fig. 3, *C*).

All the rest of the Rhizopoda differ from the Lobosa in having the pseudopodia in the shape of slender threads. Of these a remarkable and interesting group is the order **Foraminifera.** A Foraminifer has a shell which is nearly always composed of carbonate of lime. This we can readily demonstrate by placing a drop of hydrochloric or nitric acid on a mass of the shells, when they dissolve with effervescence. In some Foraminifera the shell has a wide opening on the exterior as in Difflugia and Arcella; in others there is no large opening, but the wall of the shell is perforated by a number of minute pores scattered over its surface. The greater part of the protoplasm is enclosed within the shell, but part of it (Fig. 4) streams out from the single large opening, or from the pores, in the form of slender thread-like radiating pseudopodia, which, when they come in contact with one another, may coalesce, and may in this way give rise to a network. The protoplasm in the interior contains a nucleus, but no contractile vacuole. The shape of the shell is sometimes spherical, sometimes flask-shaped, sometimes oval or elliptical. Only in a comparatively small number of Foraminifera does it remain simple (*1*, *2*); in the great majority, though the shell when first formed is simple, a little process or bud of protoplasm soon projects through the wide opening or through the pores; this increases in size, and becomes enclosed in a shell like the original one,



1. Gromia 2. Rotalia 3. Squammulina 4. Miliola

FIG. 4. — Various forms of **Foraminifera**. In *4*, Miliola, *a*, shows the living animal; *b*, the same killed and stained; *a*, aperture of shell; *f*, food particles; *nu*, nucleus; *sh*, shell. (From Bütschli's *Protozoa* and Claus's *Zoology*.)

but usually a size larger, remaining in firm connection with it, the cavities of the two remaining in communication with one another through the original opening or openings at which the bud first appeared. From this second shell in turn a bud is given off in the same manner, and the process is repeated again and again, until, instead of a single particle of protoplasm enclosed in a single shell, there is formed a composite structure, made up of a number of particles of protoplasm, each with its nucleus, and each enclosed in a shell, the whole of the shells being firmly united together, and the whole of the particles of protoplasm being in continuity through the apertures of communication. The several parts of such a compound shell, which are known as the *chambers*, are variously arranged in different Foraminifera (Fig. 5), according to the way in which the successive buds have been given off. In some the buds succeed one another in a straight line, and the compound shell which results (*3*) has consequently its chambers arranged in a straight row. Or the chambers may be developed alternately on opposite sides of the original cell (*5*), or with the new chambers entirely overlapping their predecessors (*4*). In other cases the development of the buds takes a winding course, the resulting shell having its chambers arranged in some form of spiral, like the spiral of a watch-spring or of a corkscrew. Such a spiral shell (*6—11*) assumes a great variety of forms in different Foraminifera, owing to differences, not only in the shape of the chambers themselves, but also in the nature of the spiral in which they are arranged.

In many cases the shell is further complicated by the development of what is termed the *supplemental shell* (Fig. 5, *8 b*), a deposit of carbonate of lime outside the original shell, traversed by a complex system of fine canals containing protoplasm, and sometimes produced into a number of relatively large spines.

Though the great majority of Foraminifera have dense shells composed of carbonate of lime, there are many in which the shell resembles that of Difflugia in being composed of foreign particles, such as sand-grains, cemented together; these are termed the *arenaceous* Foraminifera; some of these have one large opening, some a number of pores. In certain fresh-water forms, such as *Gromia*, the shell is chitinoid. In Gromia (Fig. 4, *1*) the chitinoid shell has a wide mouth through which the protoplasm protrudes to form a layer enclosing the shell and giving off the pseudopodia.

Little is known of the reproduction of the Foraminifera. But in some a remarkable mode of reproduction has been observed. The protoplasm in the interior of the shell divides up into a number of particles. Each of the bodies thus formed possesses, instead of pseudopodia, a single delicate whip-like appendage — the *flagellum* — which lashes to and fro and propels the embryo Foraminifer through the water. Such a flagellum-bearing embryo is termed a *flagellula*.

All the Foraminifera, with the exception of Gromia and one or two allied forms, are marine, and the greater number are *pelagic* — *i.e.*, live in the surface waters of the open sea — though they occur also inshore, and at almost all depths. The pelagic Foraminifera are most abundant in warm latitudes, where they occur in enormous numbers. The ocean floor at depths of five hundred to twenty-eight hundred fathoms is covered in many places with a mud-like deposit which effervesces and dissolves when acid is added, and which, when examined under the microscope, is found to consist mainly of the shells of Foraminifera, which must have fallen down from above on the death of the animals.

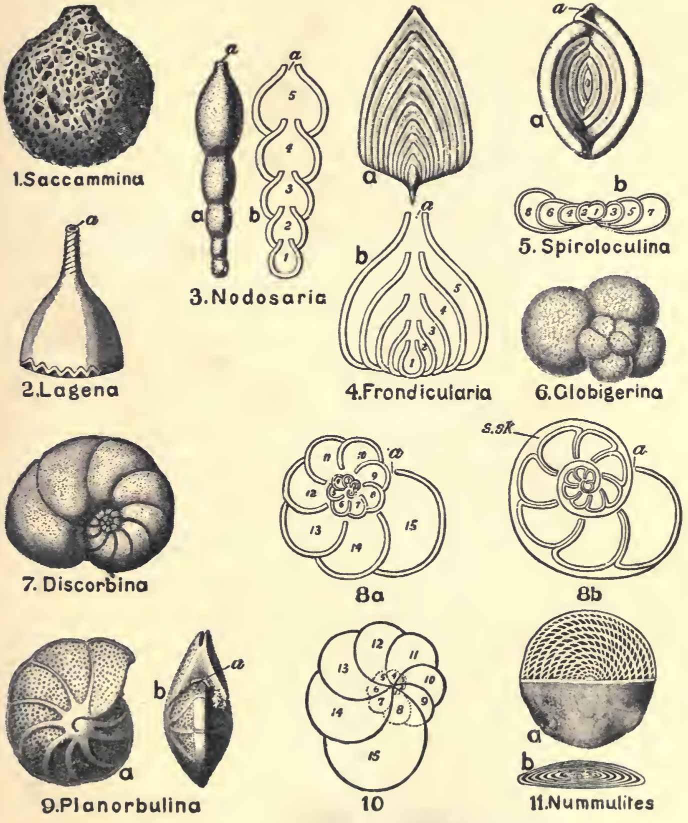

1.Saccammina
a
2.Lagena
a
a
b
5
4
3
2
1
3.Nodosaria
a
a
b
5
4
3
2
1
4.Frondicularia
a
a
b
8 6 4 2 1 3 5 7
5. Spiroloculina
6.Globigerina
7. Discorbina
a
11 10 9 12 6 7 8 13 14 15
8a
s.sk
a
8b
a
b
a
9.Planorbulina
12 11 13 5 4 10 6 9 7 8 14 15
10
a
b
11.Nummulites

FIG. 5.—Shells of **Foraminifera**. In *3, 4,* and *5, a* shows the surface view, and *b* a section; *8a* is a diagram of a coiled cell without supplemental skeleton; *8b* of a similar form with supplemental skeleton (*s. sk*); and *10* of a form with overlapping whorls; in *11a* half the shell is shown in horizontal section; *b* is a vertical section; *a*, aperture of shell; 1—15, successive chambers, 1 being always the oldest or initial chamber. (After Carpenter, Brady, and Bütschli.)

From the name of the genus — *Globigerina* (Fig. 5, *6*) — which occurs in the greatest abundance in this deposit, it is known as the *Globigerina ooze.* In the deepest parts of the ocean the Globigerina ooze is entirely absent, the calcareous shells of the Foraminifera apparently becoming entirely dissolved before they can reach such great depths. It is interesting to note that similar deposits were formed in previous geological periods — the beds of *chalk* of the Cretaceous period consisting, like the Globigerina ooze, in great measure of the shells of Foraminifera, though apparently not formed under the same conditions of depth. Another case of massive deposition of Foraminifera in a former geological period is the *Nummulitic Limestone,* a bed of limestone made up, for the most part, of the shells of comparatively gigantic Foraminifera, the Nummulites (Fig. 5, *11*).

A Rhizopod by no means uncommon in fresh water is the so-called sun-animalcule, **Actinophrys sol.** The body of Actinophrys (Fig. 6) is nearly spherical, and contains a large nucleus and numerous vacuoles, some of which, situated near the surface, are contractile. The most characteristic feature is formed by the pseudopodia, which, instead

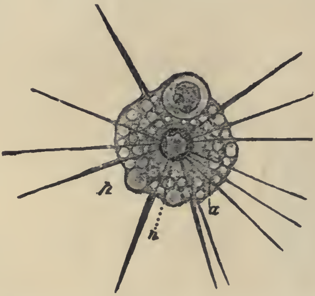


FIG. 6. — **Actinophrys sol.** *a*, axial filaments of pseudopods; *n*, nucleus; *p*, pseudopod. (From Lang's *Comparative Anatomy*, after Greenacher.)

of being comparatively short and thick, as in Amœba and in the other Lobosa, or extremely delicate, flexible, and thread-like, as in the Foraminifera, are slender, but comparatively stiff, and stand out straight from the surface of the sphere in a radiating manner: they are capable of only very slow

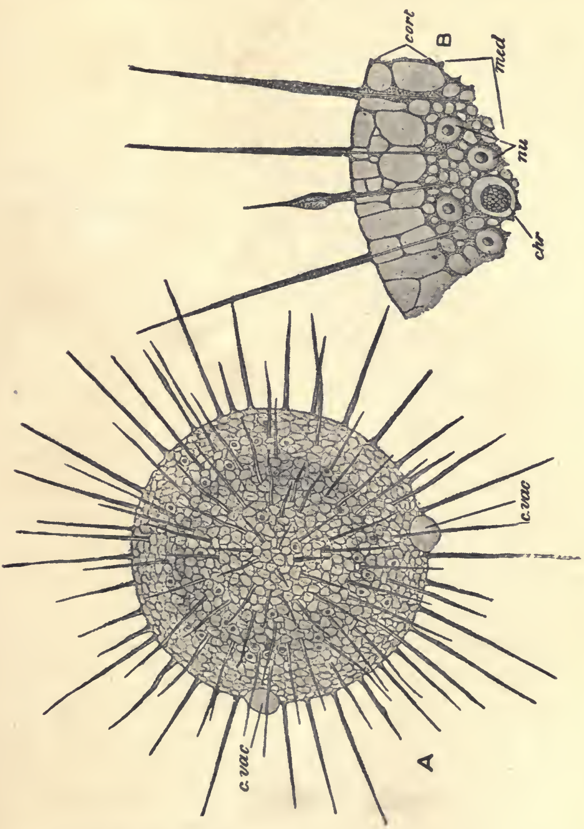


Fig. 7.—**Actinosphærium eichhornii.** A, the entire organism; B, a small portion, highly magnified; *chr*, chromatophore; *cort*, cortex; *c. vac*, contractile vacuole; *med*, medulla; *nu*, nuclei. (From Bütschli's *Protozoa*, after Hertwig and Lesser.)

movements. The pseudopodia owe their stiffness to the presence of a rod of chitinoid material which lies in the axis of each, and extends inward toward the middle of the protoplasm. A large nucleus lies in the centre of the body. A good many other genera are known which have pseudopodia of the same general character as those of Actinophrys, and these are accordingly grouped together as an order of Rhizopoda — the order **Heliozoa.** Of these other genera of Heliozoa, *Actinosphærium* (Fig. 7) is somewhat more complex in structure than Actinophrys, the protoplasm being divided into a central mass — the *endosarc* — in which the vacuoles are small, and an outer layer — the *ectosarc* — in which they are very large. Numerous nuclei are present, and bodies containing *chlorophyll* — the characteristic green colouring matter of plants. It frequently occurs in company with Actinophrys, among the leaves of Lemna and other plants, and feeds on microscopic forms, also Rotifers (Stokes). Some of the Heliozoa, instead of being composed like Actinophrys entirely of soft protoplasm, have supporting and protecting hard parts. Such hard, or comparatively hard, parts in any animal, whatever form they may assume, whether that of an enclosing shell or crust, or a system of internal bones or other firm structures, are known under the general term of *skeleton.* In those Heliozoa in which a skeleton occurs it is sometimes a shell of agglutinated sand-grains, like the shell of Difflugia, or of the arenaceous Foraminifera; or it may consist of loosely matted needle-like bodies composed of silica (Fig. 8, *1*); or there may, as in *Clathrulina*, be a sphere of silica, perforated by numerous openings, enclosing the protoplasm. *Clathrulina elegans* (Fig. 8, *3*) is common in many ponds, attached to the rootlets of Lemna, or duck-weed (Stokes).

Reproduction takes place, as in Amœba, by binary fission.

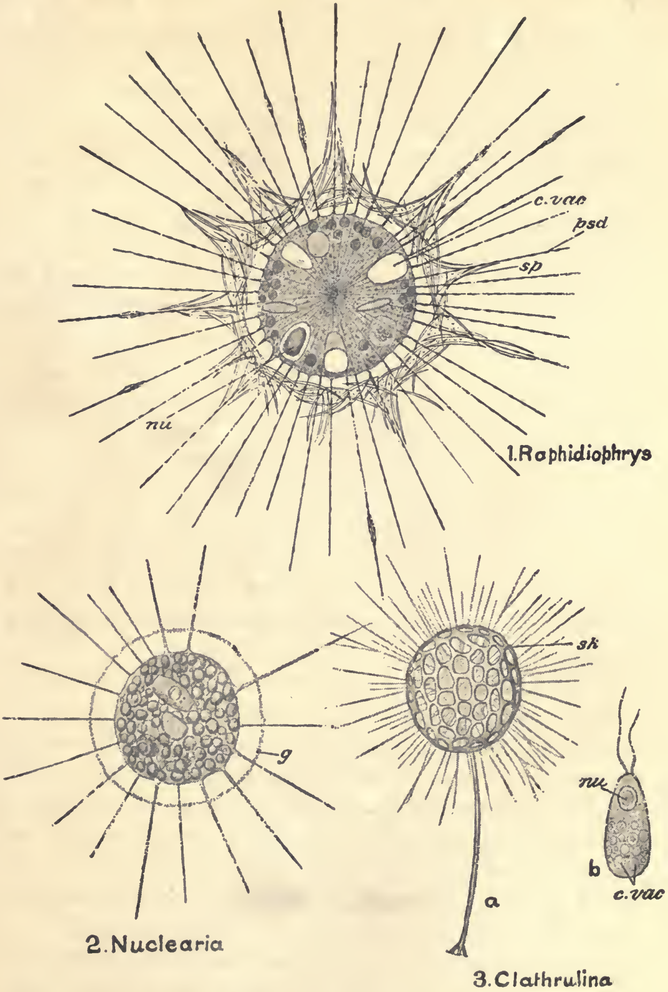

c.vac
psd
sp
nu
1.Raphidiophrys
sk
g
nu
b
c.vac
a
2.Nuclearia
3.Clathrulina

FIG. 8. — Various forms of **Heliozoa.** *3a*, the entire animal; *3b*, the flagellula; *c. vac*, contractile vacuole; *g*, gelatinous investment; *nu*, nucleus; *psd*, pseudopods; *sk*, siliceous skeleton; *sp*, spicules. (From Bütschli's *Protozoa*, after Schulze and Greeff.)

But in some genera the process of fission under some circumstances remains incomplete, the two protoplasmic bodies to which the fission gives rise remaining connected together by a bridge or isthmus of protoplasm, instead of becoming separated off in the shape of two independent animals, as in Amœba. Further, these two bodies may each in turn divide in the same incomplete way, so that four Heliozoans are developed, all remaining connected together; and by further repetitions of the same process a structure may be formed consisting of a large number of units all connected together by living substance. A structure of this kind, formed as a result of repeated incomplete division (or, in other cases, budding) from an original simple animal, is termed a *colony*, and the elements or units of which it is composed are termed *zooids*. How such a colony of unicellular Protozoa is to be distinguished from a multicellular animal or Metazoan (p. 19) will be explained at a later stage. It will at once be apparent that the compound Foraminifera are of the nature of colonies of unicellular zooids, each occupying one of the chambers of the shell, formed as the result of a process of repeated budding.

In addition to the process of multiplication by fission multiplication also takes place in some Heliozoa by a process known as the formation of *spores*. In spore-formation (a form of which has already been referred to as occurring in the Foraminifera) the protoplasm breaks up into numerous small parts, each of which eventually develops into the form of the parent. Usually the Protozoan passes into a quiescent condition before this takes place; the pseudopodia become withdrawn, and the whole becomes enclosed in a firm envelope or *sporocyst;* this process is known as *encystation*. The spores in some of the Heliozoa, when set free, are provided each with two flagella (Fig. 8, *3*, *b*) which subsequently become lost, pseudopodia appearing in their place.

The **Radiolaria** are marine Rhizopoda which have exceedingly delicate, thread-like pseudopodia (Fig. 9, *psd*) and a skeleton usually composed of silica. This skeleton may be composed of loosely woven needle-like bodies or *spicules;* more usually it is in the form of a globular, conical, star-shaped, or disc-shaped shell, perforated by numerous openings, and often supported by spines which radiate out from the centre; sometimes (Fig. 10) there are several such shells one within the other. In some Radiolaria the skeleton is composed not of silica, but of a chitinoid substance called *acanthin.* Embedded in the protoplasm is a perforated membranous sac, the *central capsule* (Figs. 9 and 10, *cent. caps*), in the protoplasm within which is a single nucleus or a number of nuclei, and a number of oil-drops. There is no contractile vacuole, but in many Radiolaria the protoplasm outside the central capsule contains numerous non-contractile vacuoles, the presence of which gives it a frothy appearance.

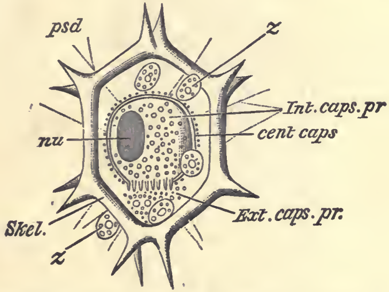


FIG. 9. — **Liteocircus annularis.** *cent. caps*, central capsule; *ext. caps. pr*, extra-capsular protoplasm; *int. caps. pr*, intra-capsular protoplasm; *nu*, nucleus; *psd*, pseudopods; *skel*, skeleton; *z*, cells of Zooxanthella. (After Bütschli, from Parker's *Biology*.)

Radiolaria which give rise to colonies are exceptional, but a few cases occur. In these (Fig. 11) the central capsule divides again and again giving rise to a number of central capsules which remain embedded in a firm gelatinous substance — the vacuolated protoplasm outside the central capsules. Such a mass, which may attain considerable size, floats about freely in the sea.

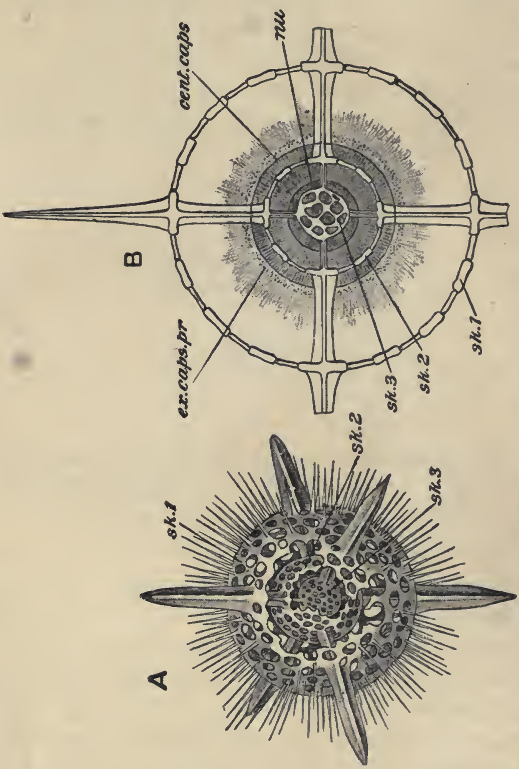


Fig. 10. — **Actinomma asteracanthion.** A, the shell with portions of the two outer spheres broken away; B, section showing the relations of the skeleton to the animal; *cent. caps*, central capsule; *ex. caps. pr*, extra capsular protoplasm; *nu*, nucleus; *sk. 1*, outer, *sk. 2*, middle, *sk. 3*, inner sphere of skeleton. (From Bütschli's *Protozoa*, after Haeckel and Hertwig.)

In addition to reproduction by simple binary fission, spore-formation also occurs in some of the Radiolaria. The protoplasm contained in the central capsule breaks up into small masses, each of which becomes a *flagellula* provided with a flagellum (Fig. 44, *E*, *F*).

In most of the Radiolaria there occur in the extra-capsular protoplasm minute yellow cells (Fig. 9, *z*), which multiply independently by binary fission. It has been proved that these are microscopic unicellular plants (*Zooxanthella*) of the class Algæ, which live in the substance of the protoplasm of the living Radiolarian. Such an intimate association between two living organisms is known as *symbiosis*. There can be no doubt that this association is beneficial both to the Radiolarian and to the Alga. It is characteristic of the plant cell that under the action of light and in the presence

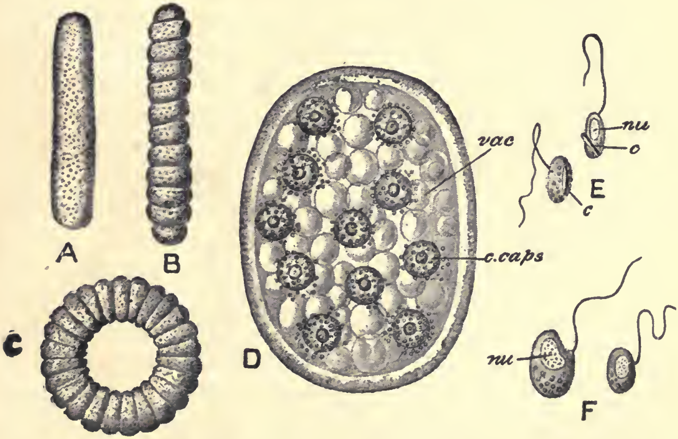


FIG. 11. — **Collozoum inerme.** A—C, three forms of the entire colony, nat. size; D, a small colony showing the numerous capsules (*c. caps*) and extra-capsular protoplasm with vacuoles (*vac*); E, spores containing crystals (*c*); mega- and microspore. (From Bütschli's *Protozoa*, after Hertwig and Brandt.)

of the specially vegetable green colouring matter, *chlorophyll*, it is able to utilise for its nutrition the carbon dioxide or "carbonic acid gas" present in the air. The carbon is seized and made use of by the plant cell for the building up of such compounds as starch and sugar, while the oxygen is set free. The animal cell, on the other hand, is continually using up oxygen and giving off carbon dioxide in the process of respiration, while it is unable, in the absence of chlorophyll, to manufacture such substances as starch and sugar. Thus in this close association or symbiosis between the Zooxanthella and the Radiolarian, the latter benefits the former by supplying it with carbonic acid and other substances by which it is nourished, while the Alga contributes to the respiration of the Radiolarian by the oxygen which it gives off, and to its nutrition by the sugar and other substances which it forms.

2. THE MASTIGOPHORA

We have seen that the spores by which multiplication is effected in some of the Rhizopoda (Heliozoa, Radiolaria) are characterised by the presence of slender whip-like appendages — the flagella. In a great number of Protozoa such a flagellate condition of the cell is not merely a temporary larval one, as in the cases already dealt with, but is the ordinary and permanent condition of the adult animal. These permanently flagellate Protozoa constitute the class **Mastigophora** — a very numerous group, mostly of very small size. A good example of this class, very abundant in fresh-water pools, in which it may be present in such enormous numbers as to impart to the water a distinct green colour, is **Euglena viridis** (Fig. 12). Another species or variety of *Euglena viridis*, is so abundant at times as to colour the water blood-red (Stokes).

The body of Euglena (*E, H*) is spindle-shaped, and has at the blunt anterior end a depression, the *gullet* (*F. œs*), from the inner surface of which springs a single long flagellum (*fl*). The organism is propelled through the water by the lashing movements of the flagellum, which is always directed forwards; it can also perform slow, worm-like movements of contraction and expansion (*A—D*), but anything like the

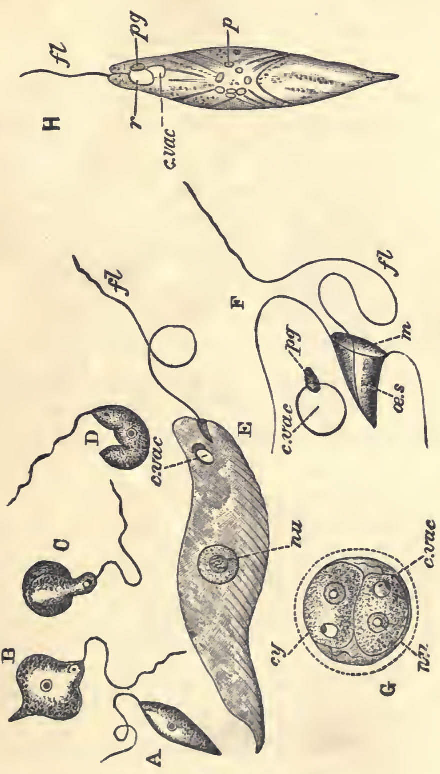


FIG. 12.—**Euglena viridis.** A—D, four views illustrating euglenoid movements; E and H, enlarged views; F, anterior end further enlarged; G, resting form after binary fission; *c. vac*, contractile vacuole in H, reservoir in E and F; *cy*, cyst; *fl*, flagellum; *m*, mouth; *nu*, nucleus; *œs*, gullet; *p*, paramylum bodies; *pg*, pigment spot; *r* (in H), reservoir. (From Parker's *Biology*, after Kent and Klebs.)

free pseudopodial movements which characterise the Rhizopoda, is precluded by the presence of a very thin skin or cuticle which invests the body. There is a nucleus (*nu*) near the centre of the body, and at the anterior end a contractile vacuole (*H, c. vac*), leading into a large non-contractile space or *reservoir* (*r*) which discharges into the gullet.

The greater part of the body is coloured green by the characteristic vegetable pigment, chlorophyll, and contains grains of *paramylum* (*H, p*), a carbohydrate allied to starch. In contact with the reservoir is a bright red speck, the *stigma* (*pg*), formed of a pigment allied to chlorophyll and called *hæmatochrome*. It seems probable that the stigma is a light-perceiving organ or rudimentary eye.

Euglena is nourished like a typical green plant; it decomposes the carbon dioxide of the air dissolved in the water, assimilating the carbon and setting free the oxygen. Nitrogen and other elements it absorbs in the form of mineral salts in solution in the water. But it has also been shown that the movements of the flagellum create a whirlpool by which minute fragments are propelled down the gullet and into the soft internal protoplasm. There seems to be no doubt that in this way minute organisms are taken in as food. Euglena thus combines the characteristically animal (*holozoic*) with the characteristically vegetable (*holophytic*) mode of nutrition.

Sometimes the active movements cease; the animal comes to rest and surrounds itself with a cyst or cell-wall of cellulose (the characteristic material of the cell-wall of plants), from which, after a quiescent period, it emerges to resume active life. It is during the resting condition that reproduction takes place by the division of the body in a median plane parallel to the long axis (*G*). Under certain circumstances

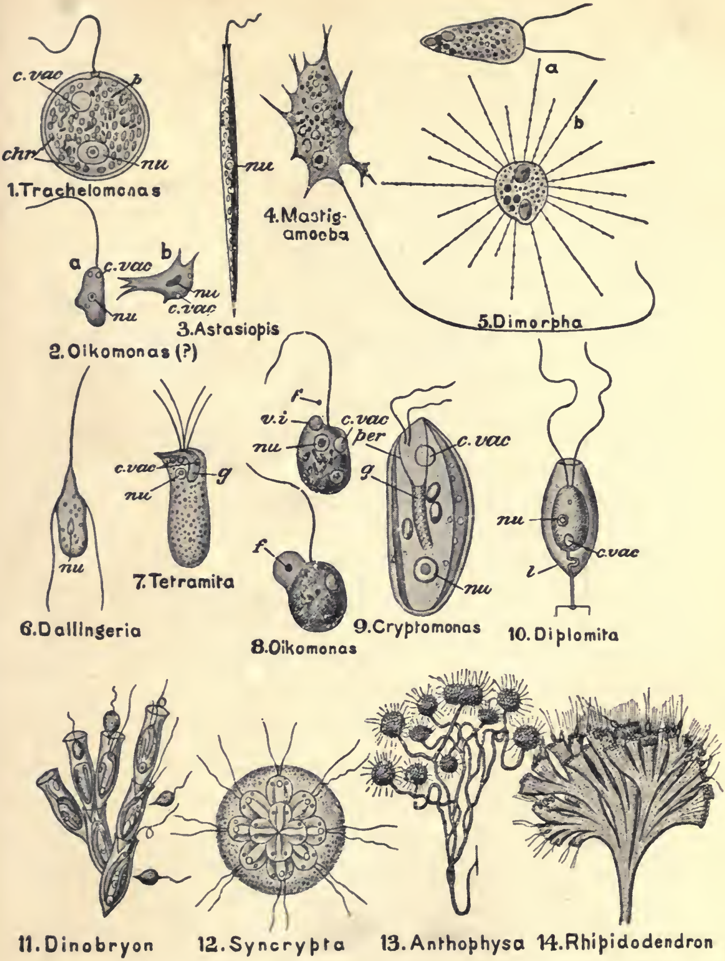

c. vac
p
chr
nu
1. Trachelomonas
nu
3. Astasiopis
4. Mastigamoeba
a
b
5. Dimorpha
a
c. vac
b
nu
c. vac
nu
2. Oikomonas (?)
nu
6. Dallingeria
c. vac
g
nu
7. Tetramita
f
v. i
c. vac
nu
f
8. Oikomonas
per
c. vac
g
nu
9. Cryptomonas
nu
c. vac
l
10. Diplomita
11. Dinobryon
12. Syncrypta
13. Anthophysa
14. Rhipidodendron

FIG. 13. — Various forms of **Mastigophora**. In *2*, flagellate (*a*) and amœboid (*b*) phases are shown; in *5*, flagellate (*a*) and heliozoan (*b*) phases; in *8* are shown two stages in the ingestion of a food particle (*f*); *chr*, chromatophores; *c. vac*, contractile vacuole; *f*, food particle; *g*, gullet; *nu*, nucleus; *l*, lorica; *p*, protoplasm; *per*, peristome; *v. i*, vacuole of ingestion. (Mostly from Bütschli's *Protozoa*, after various authors.)

multiple fission takes place, and *flagellulæ*, *i.e.*, young provided with flagella, are produced, which, sometimes after passing through an amœboid stage, develop into the adult form.

In the other Mastigophora the body may have a shape similar to that of Euglena, or may be longer and narrower, or, on the other hand, may be short and thick, ovoid or globular. Anterior and posterior ends are nearly always distinguishable, the former being that which is directed forwards in progression. Usually there are distinct dorsal and ventral surfaces, the former being that which is habitually directed upwards. In most cases the body is equal-sided or bilaterally symmetrical, *i.e.*, is capable of being divided into two equal lateral portions along the median vertical plane; but sometimes it is unsymmetrical, one side differing more or less from the other. In most the body is, as in Euglena, naked; but some have a chitinoid shell or *lorica*, while others have a firm cell-wall of cellulose which may present an elaborate pattern of strips, dots, etc., and may be produced into long processes. Most of the Mastigophora are, like Euglena, free-swimming, but some are permanently attached by means of a slender stalk (Fig. 13, *10*, *13*, *14*; Fig. 14, *1*, *3*).

The number and arrangement of the flagella vary greatly. The number may be one, as in Euglena, or two, three, or four. In forms with two flagella these are both attached at or near the anterior end, and often take on different functions, one of them, directed forwards, being alone used in locomotion, while the other is trailed behind when the animal is swimming freely, or is used to anchor it to various solid bodies. In one large group of Mastigophora, the **Choanoflagellata** (Fig. 14), there is, surrounding the base of the flagellum, a remarkable vase-like prolongation of the protoplasm, exceedingly delicate and transparent, called the *collar*. This is contractile, and, though its precise functions are not yet

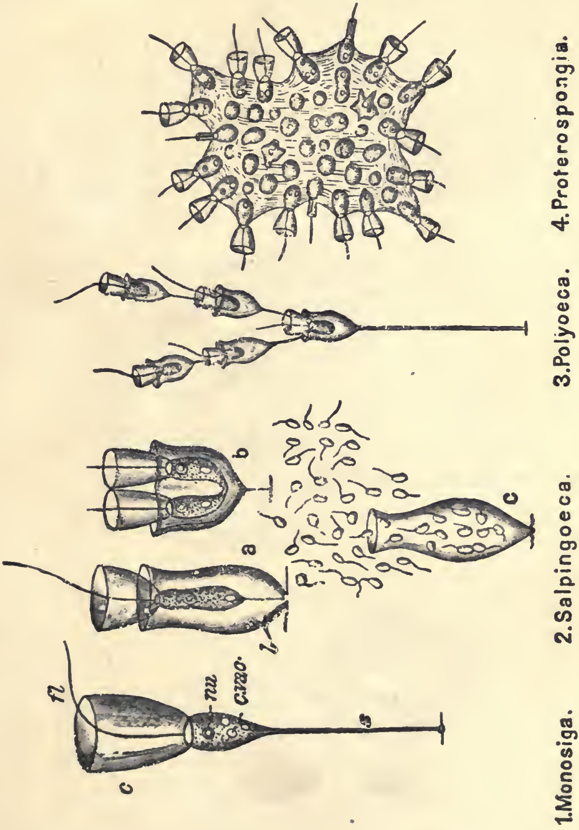

1.Monosiga.
c
fl
nu
c.vac.
s
2.Salpingoeca.
l
a
b
c
3.Polyoeca.
4.Proterospongia.

FIG. 14. — Various forms of **Choanoflagellata**. *2b* illustrates longitudinal fission; *2c*, the production of flagellulæ; *c*, collar; *c. vac*, contractile vacuole; *fl*, flagellum; *l*, lorica; *nu*, nucleus. (After Saville Kent.)

certainly known, there is evidence to show that its movements cause a flow of water, with minute particles in suspension, up the outside of the collar and down the inside, the solid particles being then ingested in the soft protoplasm between the base of the flagellum and that of the collar. Both collar and flagellum may be withdrawn, and the animal pass into an Amœba-like or *amœboid* form. In another group — the **Dinoflagellata** (Fig. 15) — there are two flagella, one springing from a longitudinal groove extending along the anterior half of the body, and the other lying in a

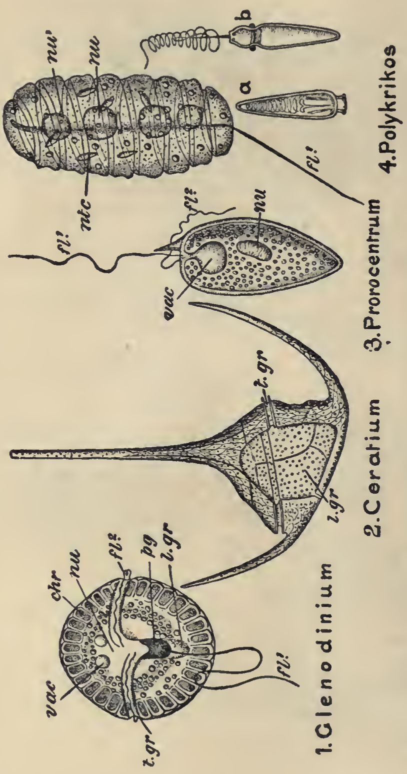

vac
chr
nu
fl²
pg
l.gr
t.gr
fl¹
1.Glenodinium
t.gr
l.gr
2.Ceratium
vac
fl¹
fl²
nu
3.Prorocentrum
ntc
nu
nu'
fl¹
a
b
4.Polykrikos

FIG. 15.—Various forms of Dinoflagellata. *2* shows the shell only; *4a* is an undischarged, and *b* a discharged stinging-capsule; *chr*, chromatophores; *fl. 1*, longitudinal flagellum; *fl. 2*, transverse flagellum; *l. gr*, longitudinal groove; *ntc*, nematocyst; *nu*, meganucleus; *nu'*, micronucleus; *pg*, pigment spot; *t. gr*, transverse groove. (From Bütschli's *Protozoa*.)

transverse groove which completely encircles the body; the former alone acts as an organ of locomotion, the latter lies habitually in the groove and performs undulating movements. **Noctiluca (Cystoflagellata)** (Fig. 16), which is the largest member of the class, being about half a millimetre in diameter, has two flagella, one of which is modified in a remarkable manner. The body of Noctiluca is globular, with a cleft along one side so that it resembles a miniature peach. From this springs a very large and stout flagellum or *tentacle*, which is marked with a number of transverse lines or striations; and a second flagellum, of comparatively small size, lies in the gullet.

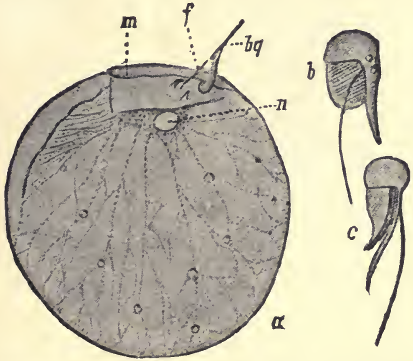


Fig. 16.—**Noctiluca miliaris.** *a*, the adult animal; *b*, *c*, flagellulæ; *bg*, tentacle; *f*, flagellum; *m*, mouth; *n*, nucleus. (From Lang, after Bütschli.)

Though all the Mastigophora are characterised by the possession of flagella, there are a few, such as *Mastigamœba* (Fig. 13, *4*), which also possess pseudopodia, and may be capable of amœboid movements.

Nutrition is effected in a variety of different ways. Some forms live in decaying organic infusions, not taking in solid food-particles, but absorbing nourishing matter in a dissolved form from the substances in the infusion. Others, living in internal cavities of the bodies of higher animals, receive, in a similar way, nourishment from the juices of the animal they infest. Organisms, whether plants or animals, which receive their nourishment in the former of these two ways, are said to be *saprophytic* as regards their nutrition, while such as obtain it from other living organisms are said to be *parasitic*. But a large proportion of the Mastigophora are neither saprophytes nor parasites, and are nourished in one of two other ways, or in both of them. Many take in minute solid particles of organic matter, usually in the form of minute living organisms. In many such cases, there is, as in Euglena, an aperture, the mouth, opening into a short passage, the gullet, by which the food is received into the protoplasm in the interior of the body; but this is not always present, and in such cases (Fig. 13, *8*) the food-particles are taken in by a process not unlike that which we have seen to occur in Amœba. But, on the other hand, many of the Mastigophora are not distinguishable from plants by their mode of nutrition; and on that ground, taken in connection with their structure, which is in nearly all respects that of a typical unicellular plant, have almost equal claims to be ranked in either the vegetable or the animal kingdom. They have a cell-wall of cellulose like a plant cell, they contain chlorophyll or a red colouring matter, *hæmatochrome*, of similar composition, and they have no mouth. They must, therefore, be nourished precisely after the manner of a green plant, and, if they are assigned to the animal kingdom instead of to the vegetable, it can only be because the possession of flagella seems to ally them with forms that are of undoubted animal character.

Colonies are of frequent occurrence among the Mastigophora. Sometimes there is a branching slender stalk bearing a single zooid or a group of zooids at the end of each of the branches (Fig. 14, *3*), the whole colony being fixed by the base of the main stalk, and the flagellum serving for the capture of food-particles and not for locomotion.

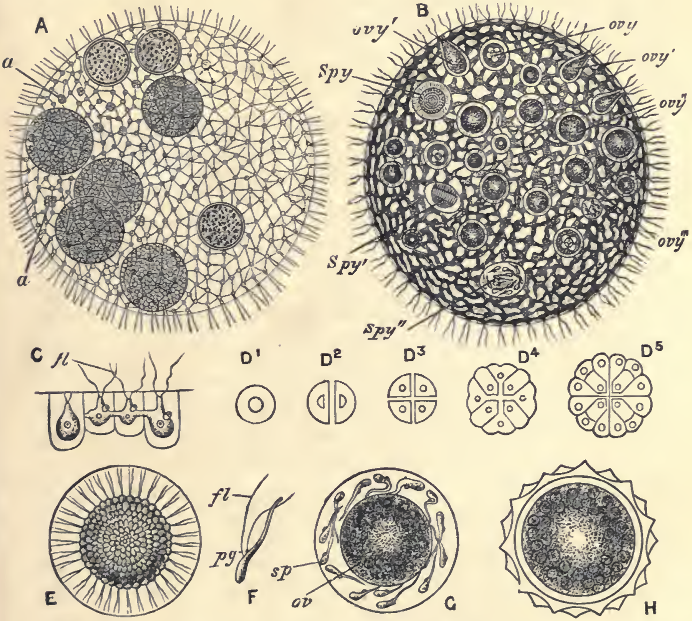


FIG. 17. — **Volvox globator.** A, entire colony, enclosing several daughter-colonies; B, the same during sexual maturity; C, four zooids in optical section; D^1—D^5, asexual formation of daughter-colony; E, zooid which has become converted into a mass of microgametes; F, microgamete; G, megagamete surrounded by microgametes; H, zygote; *a*, early stages in the formation of daughter-colonies; *fl*, flagellum; *ov*, *ovy*, megagametes; *pg*, pigment spot; *spy*, zooids containing microgametes. (From Parker's *Biology*, after Cohn and Kirchner.)

Sometimes (Fig. 17) the colony is of a more massive character, the zooids being embedded in a clump of gelatinous material, with the end bearing the flagellum projecting on the exterior: usually such colonies are free-swimming.

Multiplication is effected most commonly by the simple process of binary fission (Fig. 11, *2b*), which may take place either in the active or in an encysted condition. In some cases the fission is *multiple*, the protoplasm dividing not merely into two, but into a greater number of parts, each destined to develop into the adult form.

We also meet in the Mastigophora with what may be regarded as the simplest mode of *sexual* reproduction. In some forms two individuals come together and become completely fused, the process being known as *conjugation*,[1] and the body formed by the union of the cells being known as a *zygote*. The protoplasm of the latter divides by multiple fission into very minute spores. These, when first liberated by the rupture of the zogote, are mere granules, but soon the flagella are developed. In some cases the conjugating cells or *gametes* are of two sizes, union always taking place between a large cell or *megagamete* and a small cell or *microgamete*. In Volvox, which is a free-swimming spherical colony (Fig. 17, *E*, *F*, *G*) this difference between the two sets of conjugating cells reaches its extreme, producing a condition of things closely resembling what we find in the sexual reproduction of higher forms. Certain of the zooids enlarge and form megagametes, others divide repeatedly and give rise to groups of microgametes, each of the latter having the form of a rod-like body with two flagella. The microgametes escaping, swim about freely and conjugate with the motionless megagametes to form a zygote, which, after a time divides to give rise to a new colony.

Mastigophora occur under the most various conditions, to some of which reference has been already made. Many kinds live in fresh water; others are abundant in the sea. Noctiluca and others among the marine forms are phosphorescent, and are usually the agents by means of which the diffuse phosphorescence of the sea is produced. Others, again, are saprophytes, while others are parasites of higher animals.

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[1] Conjugation has also been observed to occur in many Rhizopods.

3. THE INFUSORIA

Often to be found in great numbers, in stagnant pools, organic infusions, etc., is **Paramœcium,** the "slipper-shaped animalcule," a Protozoan of comparatively large size, about $\frac{1}{4}$ mm. in length, which moves about very actively like Euglena, but with a more regular and more rapid movement, and by means of organs of locomotion differing in character from the flagellum of the latter. The body of Paramœcium (Fig. 18, *A*, *B*) is covered with what appear under the microscope like small delicate hairs arranged in longitudinal rows. These are the *cilia;* they are in incessant to-and-fro vibration, and it is by their means that the Paramœcium moves about and obtains its food. In shape the body is somewhat cylindrical, rounded at the anterior and bluntly pointed at the posterior end. On one side, the *ventral*, is a large oblique depression, the *buccal groove* (*buc. gr*), leading into a short gullet (*gul*), which, as in Euglena, ends in the soft internal protoplasm. The protoplasm is differentiated into a firmer superficial layer, the *cortex* (*cort*), and a semi-fluid central mass, the *medulla* (*med*), and is covered superficially by a thin cuticle. The cilia are prolongations of the cortex, and perforate the cuticle.

In the cortex are found two nuclei. One of these, the *meganucleus* (*nu*), is a comparatively large ovid body; the other, the *micronucleus* (*pa. nu*), is a small rounded body closely applied to the meganucleus. Two contractile vacuoles (*c. vac*) are present. Each is connected with a series of radiating spindle-shaped cavities in the protoplasm which serve as feeders to it; after the contraction of the vacuole these cavities are seen gradually to fill, apparently receiving water from the surrounding protoplasm; they then contract, discharging the water into the vacuole, the latter rapidly enlarging while they disappear from view; finally the vacuole contracts and discharges its contents externally.

The cortex contains minute radially-arranged sacs called *trichocysts* (*trch*). When the animal is irritated, more or fewer of these suddenly discharge a long delicate thread (C), which, in the condition of rest, is very probably coiled up within the sac.

Food, in the form of small living organisms, is taken in by means of the current caused by the cilia of the buccal groove. The food-particles, enclosed in a globule of water, or "food-vacuole" (*f. vac*), circulate through the protoplasm, where the soluble parts are gradually digested and assimilated. Effete matters are egested at a definite *anal spot* posterior to the mouth, where the cortex and cuticle are less resistant than elsewhere. The whole feeding process can readily be observed in this and other Infusoria by placing in the water some insoluble colouring matter, such as carmine or indigo, in a fine state of division, the minute particles of the colouring matter, which are taken into the mouth in the way described, being readily observed as they become received into food-vacuoles and circulate in the central protoplasm.

Multiplication takes place by transverse fission (D), the division of the body being preceded by that of both nuclei. It has been proved, however, that multiplication by binary fission cannot go on indefinitely, but that after it has been repeated a certain number of times, it is interrupted by

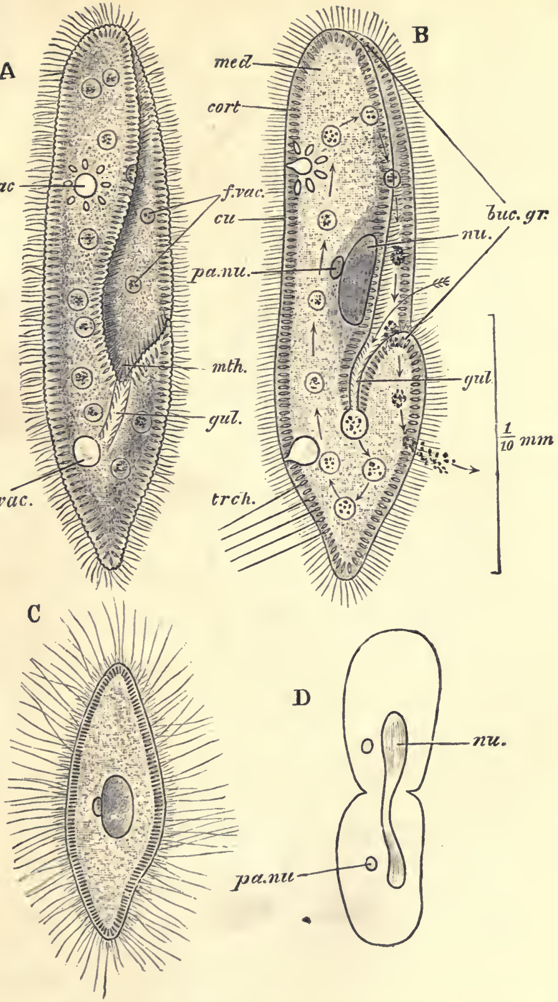

A
B
C
D
med
cort
c.vac
f.vac.
cu
buc. gr.
nu.
pa.nu.
mth.
gul.
gul
c.vac.
trch.
1/10 mm
nu.
pa.nu

FIG. 18. — **Paramœcium caudatum.** A, the living animal from the ventral aspect; B, the same in optical section: the arrow shows the course taken by food-particles; C, a specimen which has discharged its trichocysts; D, diagram of binary fission; *buc. gr*, buccal groove; *cort*, cortex; *cu*, cuticle; *c. vac*, contractile vacuole; *f. vac* food vacuole; *gul*, gullet; *med*, medulla; *nu*, meganucleus; *pa. nu*, micronucleus; *trch*, trichocysts. (From Parker's *Biology*.)

conjugation. In this very remarkable and characteristic process two Paramœcia become applied by their ventral faces, but do not fuse; their meganuclei break up and disappear, and an interchange of the substance of the micronuclei of the two conjugating individuals takes place, with the result that each develops a new meganucleus, and a new micronucleus, partly formed of the substance of its own micronucleus, partly that of the other Paramœcium.

The possession of cilia is the distinctive feature of the class **Infusoria** among the Protozoa. But in one section of the class — the order **Tentaculifera** — cilia are only present in the young, their place in the adult being taken by appendages known as *tentacles.* The form of the body in the Infusoria (Fig. 19) is very varied; it may be globular, ovoid (*1*), kidney-shaped (*2*), trumpet-shaped (*3*), vase-shaped (*9*), produced into a long, flexible, neck-like process (*5*), or into large paired lappets (*6*), flattened from above downwards, or elongated and divided into a series of segments. Most are free-swimming, but many are fixed, usually by means of a slender stalk (*9*).

The arrangement of the cilia also varies greatly. Some, like Paramœcium, have small cilia of uniform character distributed over the entire surface. Others have different kinds of cilia on different parts of the surface, while in others the cilia are entirely confined to certain regions. An instance of the latter arrangement is the common stalked form *Vorticella*, with its allies such as *Epistylis* (*9*), in which the cilia are confined to the free extremity. These cilia produce rapid currents, and the *Epistylis*, says Stokes, select from them anything they may want, and let the rest sweep by. In another group, again, the body, which is of flattened shape, bears on its dorsal surface a small number of very fine motionless cilia, while on its ventral the cilia are

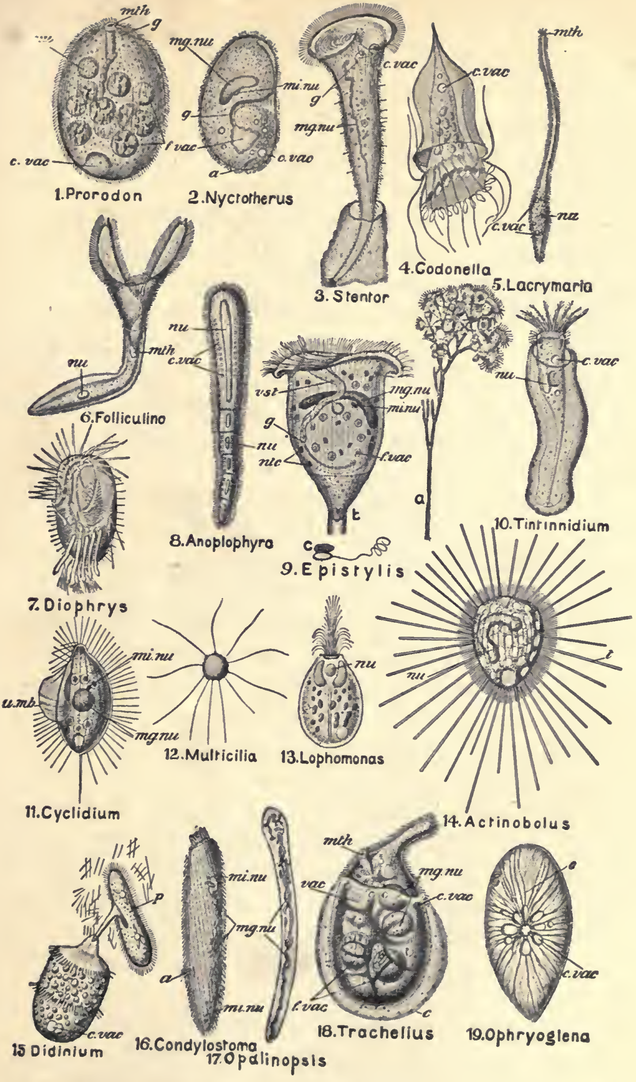

mth
g
nu
c. vac
f vac
1.Prorodon
mg.nu
mi.nu
g
f vac
c.vac
a
2.Nycrotherus
c.vac
g
mg.nu
3. Stentor
c.vac
4.Codonella
mth
nu
c.vac
5.Lacrymaria
nu
mth
6.Folliculina
nu
c.vac
nu
8.Anoplophyra
vst
mg.nu
mi.nu
g
nu
ntc
f.vac
t
c
9.Epistylis
a
c.vac
nu
10.Tintinnidium
7. Diophrys
mi.nu
u.mb
mg.nu
11.Cyclidium
12.Multicilia
nu
13.Lophomonas
nu
t
14.Actinobolus
p
c.vac
15 Didinium
mi.nu
mg.nu
a
mi.nu
16.Condylostoma
17.Opalinopsis
mth
mg.nu
vac
c.vac
f.vac
c
18.Trachelius
e
c.vac
19.Ophryoglena

Fig. 19. — Various forms of **Ciliata**. *9a* shows part of a colony, *b* a single zooid, and *c* a couple of nematocysts; *a*, anus; *c. vac*, contractile vacuole; *f. vac*, food vacuole; *g*, gullet; *mg. nu*, meganucleus; *mi. nu*, micronucleus; *mth*, mouth; *nu*, nucleus; *ntc*, nematocyst; *t*, tentacle; *u. mb*, undulating membrane; *vac*, non-contractile vacuole; *vst*, vestibule. (From Bütschli's *Protozoa*, after various authors.)

very strong, and are modified into the shape of hooks, bristles, or plates with fringed ends. The hooks and plates do not vibrate rhythmically like ordinary cilia, but are moved as a whole at the will of the animal, such Infusoria being able, in addition to swimming freely through the water, to clamber by the aid of these specially modified cilia over the surface of weeds, etc. Tentacles may be present in addition to cilia (14), and a number of other exceptional modifications (*10–13*) occur which cannot be specially referred to here.

In addition to cilia, many genera possess delicate sheets of protoplasm, or *undulating membranes* (*u. mb*) in connection with the peristome. These contract so as to produce a wave-like movement which aids in the ingestion of food.

The *tentacles*, which, in the **Tentaculifera** (Fig. 20), take the place of cilia in the adult, are elongated cylindrical structures, capable of protrusion and retraction, and having the distal end expanded into a sucker. The tentacle is practically tubular, the core consisting of a semi-fluid protoplasm, while the outer part is tolerably firm. Infusoria and other organisms are caught by the tentacles, the cuticle of the prey is pierced or dissolved where the sucker touches it, and the semi-fluid protoplasm can then be seen flowing down the tentacle into the body of the captor. A single tentacle alone may be present (*3*), or the tentacle may be branched (*4*), the extremity of each of the branches being suctorial. In some forms (*5*) the tentacles are devoid of sucker-like extremities, and can be moved about actively to catch the prey.

The meganucleus is often ovoid, as in Paramœcium. In other cases it may be long and band-like (Fig. 19, *3*, *mg. nu*), horseshoe-shaped (*9*), very long and constricted

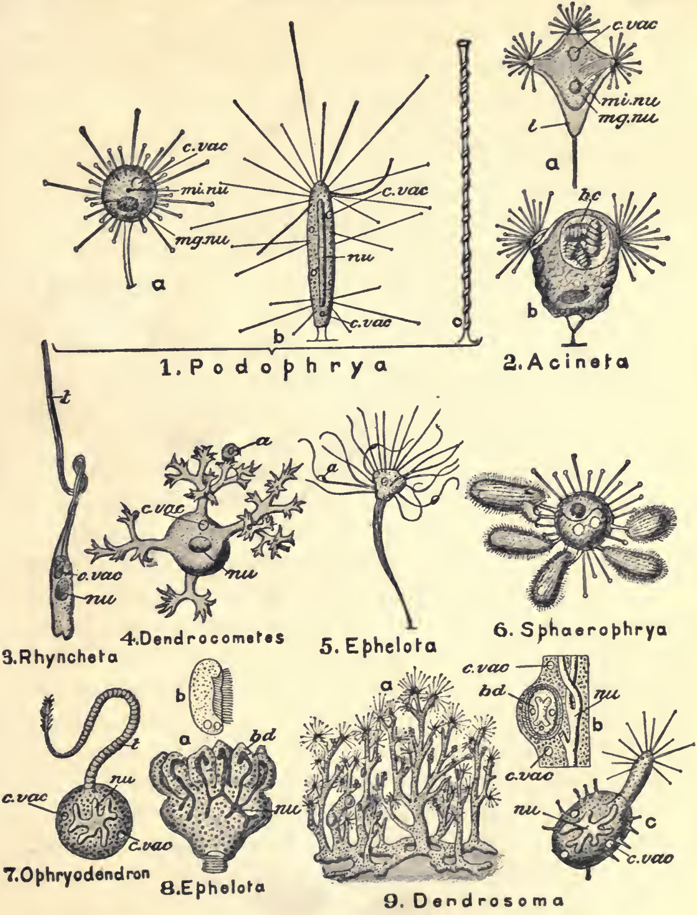

c.vac
mi.nu
mg.nu
a
c.vac
nu
c.vac
b
c
1. Podophrya
c.vac
mi.nu
mg.nu
t
a
b.c
b
2. Acineta
t
c.vac
nu
3. Rhyncheta
a
c.vac
nu
4. Dendrocometes
a
5. Ephelota
6. Sphaerophrya
t
nu
c.vac
c.vac
7. Ophryodendron
b
a
bd
nu
8. Ephelota
a
c.vac
bd
nu
b
c.vac
nu
c
c.vac
9. Dendrosoma

FIG. 20. — Various forms of **Tentaculifera**. *1a* and *b*, two species of *Podophrya;* *c*, a tentacle much enlarged; *2a*, *Acineta jolyi;* *2b*, *A. tuberosa;* in *b* the animal has captured several small Ciliata; *8a*, a specimen multiplying by budding; *8b*, a free ciliated bud; *9a*, the entire colony; *9b*, a portion of the stem; *9c*, a liberated bud; *a*. organism captured as food; *b. c*, brood cavity: *bd*, bud; *c. vac*, contractile vacuole; *mg. nu*, meganucleus; *mi. nu*, micronucleus; *t*, tentacle. (After Bütschli and Saville Kent.)

at intervals so as to look like a string of beads, or branched. In nearly all cases one or more micronuclei are present. In Vorticella and others there is a single contractile vacuole which opens, as in Euglena, through the intermediation of a reservoir into the gullet. In other Infusoria there may be one, two, or many contractile vacuoles. In some instances the protoplasm is hollowed out by numerous non-contractile vacuoles. Trichocysts mainly occur in the forms with a uniform coating of cilia: more complicated bodies of similar character termed *nematocysts* (*9*, *c*) occur in some cases.

A mouth is absent in many parasitic forms, and nourishment is obtained by the absorption of the digested food of the animal in which the infusorian is parasitic. In the Tentaculifera, in which a mouth is also absent, nourishment is drawn in by means of the tentacles in the manner already described. In the rest there is a mouth and gullet, usually situated, as in Paramœcium, at the end of a buccal groove, or peristome.

In Vorticella and its allies (Fig. 19, *9*, and Fig. 22) the body is in the shape of a wine-glass, the stem of which is represented by a slender stalk (*st*), while the rim is the equivalent of the peristome (*per*); in the area which the peristome encloses is an elevated disc of protoplasm, between which and the peristome on one side is the opening of the mouth (*mth*): the only cilia present run in a spiral band round the peristome, round the edge of the disc, and down into the gullet (*gull*). An anal spot is present in Vorticella and many other forms; in a few there is, instead, a distinct anal aperture (Fig. 19, *2 a*).

A chitinoid skeleton (Fig. 21) occurs in a few forms; usually it is bell-shaped, sometimes it is perforated by a number of apertures (*1*) so that it resembles in appearance the skeleton of some of the Radiolaria. A chitinoid lid or *operculum* (*2*, *3*, *op*) may be fixed to the edge of the peristome, and when the animal is retracted into its case, accurately closes the mouth of the latter.

Colonies occur in many of the Infusoria. Some allies of

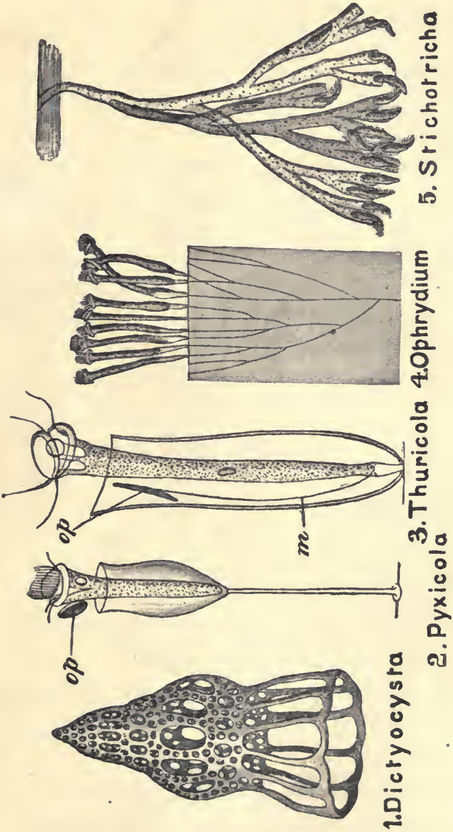

1. Dictyocysta
2. Pyxicola
3. Thuricola
4. Ophrydium
5. Strichotricha
op
op
m

FIG. 21.—Various forms of Ciliata. In *1* the shell alone is shown. *m*, contractile fibre; *op*, operculum. (From Bütschli's *Protozoa*, after various authors.)

Vorticella (Fig. 19, *9*) develop highly complex colonies, the slender stalk branching again and again, and each terminal branch ending in a zooid. A remarkable colonial form is

Dendrosoma (Fig. 20, *9*), one of the Tentaculifera: it has a creeping stem from which branches spring upwards, each terminating in a zooid with suctorial tentacles; and

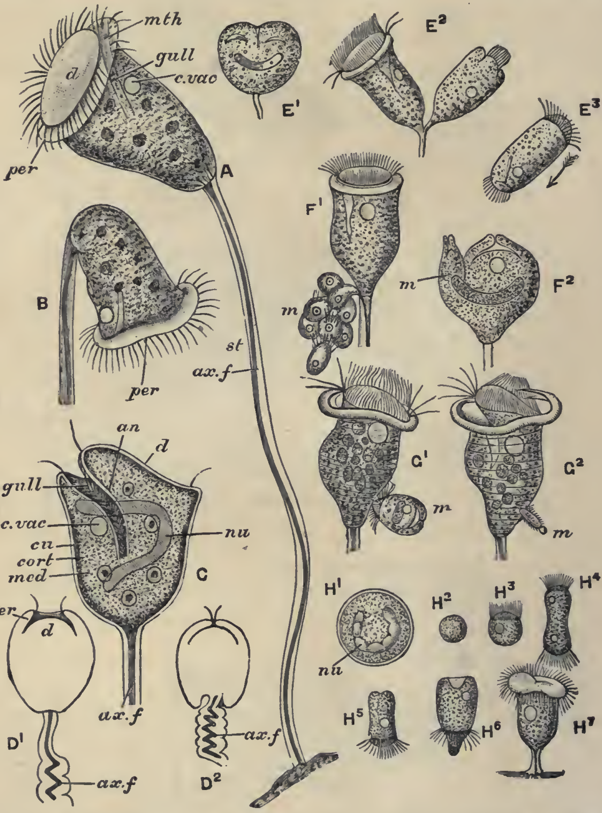

mth
gull
c.vac
d
per
A
E¹
E²
E³
F¹
F²
m
m
B
st
ax.f
per
an
d
gull
c.vac
cu
cort
med
nu
C
G¹
G²
m
m
per
d
D¹
ax.f
ax.f
D²
ax.f
H¹
nu
H²
H³
H⁴
H⁵
H⁶
H⁷

FIG. 22.—**Vorticella.** A, B, living specimens in different positions; C, optical section; D^1, D^2, diagrams illustrating coiling of stalk; E^1, E^2, two stages in binary fission; E^3, free zooid; F^1, F^2, division into mega- and microzooids; G^1, G^2, conjugation; H^1, multiple fission of encysted form; H^2, H^3, development of spores; *ax. f*, axial fibre; *cort*, cortex; *cu*, cuticle; *c. vac*, contractile vacuole; *d*, disc; *gull*, gullet; *m*, microzooid; *mth*, mouth; *nu*, meganucleus; *per*, peristome. (From Parker's *Biology*, partly after Saville Kent.)

the single nucleus extends as a narrow branching cord throughout the axis of the entire colony.

Transverse fission is the universal method of reproduction; and budding also occurs. Spore-formation has been observed in a few forms.

Conjugation, in the form of a temporary union of two individuals, with interchange of the substance of the micronuclei, occurs in many of the ciliate Infusoria. In some forms the conjugating individuals become completely fused. The effect of the process of conjugation seems to be increased activity in multiplication by fission.

In mode of life the Infusoria are as varied as the Mastigophora. Some are holozoic, some saprophytic, some parasitic. Of the parasitic forms some give rise to definite diseases in the bodies of their hosts. The skin affection known as eczema, for example, seems to be caused by the presence of parasitic Vorticellæ.

4. THE SPOROZOA

In the interior of certain organs, termed the seminal vesicles, of the earthworm will often be found a parasitic Protozoan — **Monocystis agilis** (Fig. 23) — which exemplifies another of the classes of the phylum, the class **Sporozoa**. It is flattened, elongated, pointed at both ends, and performs slow movements of expansion and contraction (*A*, *B*), reminding us of those of Euglena. There are neither pseudopodia, nor flagella, nor cilia. There is a firm cuticle, and the protoplasm is divided into a denser superficial portion, the *cortex*, and a central semi-fluid mass, the *medulla*. There is a large clear nucleus, but no trace of contractile vacuole, or of mouth or gullet. Reproduction takes place by a peculiar and characteristic process of spore-formation. Either a single individual, or two individuals closely applied together, but not actually fused, become encysted. Multiple fission then takes place, the protoplasm becoming divided (*C*) into an immense number of spindled-shaped spores, each surrounded by a strong

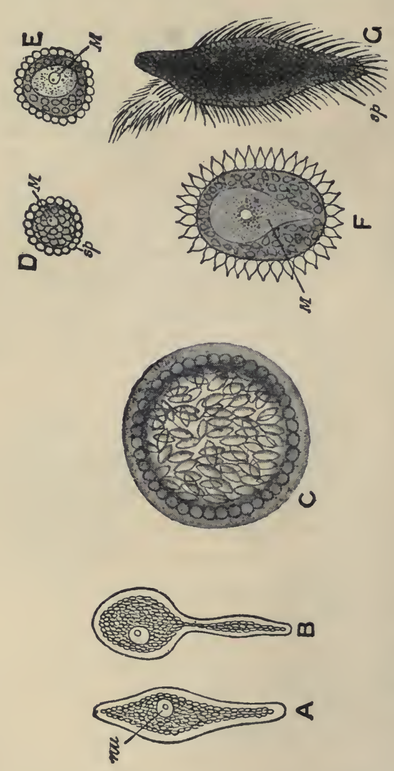


Fig. 23.—**Monocystis agilis.** A, B, two individuals in different stages of contraction; C, cyst containing spores; D—F, development of young (M) in a group of sperm-cells of the earthworm; G, newly liberated Monocystis surrounded by sperms of the earthworm; *M*, young Monocystis; *nu*, nucleus; *sp*, sperms of sperm-cells of earthworm. (After Bütschli and Huxley.)

chitinoid coat, and thus differing markedly from the naked spores of Rhizopoda and Mastigophora. The protoplasm of each spore then undergoes fission, becoming divided into a number of somewhat sickle-shaped bodies, which are arranged within the spore-coat somewhat like a bundle of sausages. By rupture of the spore-coat these *falciform young*, as they are termed, are liberated, and at once begin active movements, the thin end of the body moving to and fro like a clumsy flagellum. They enter the clumps of developing sperms of the earthworm, and afterwards escape into the cavity of the seminal vesicle and grow into the adult form.

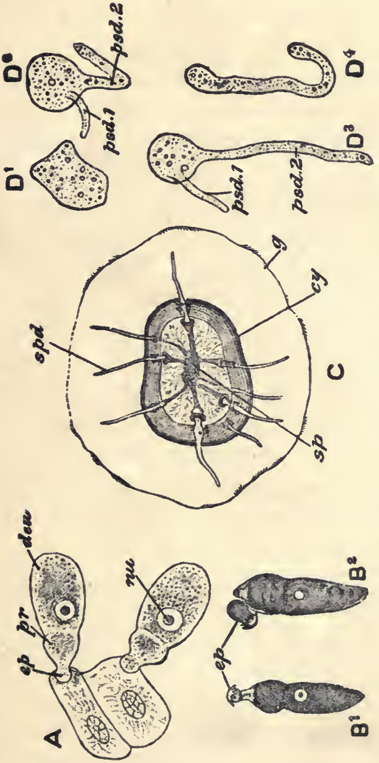


FIG. 24.—**Gregarina.** A, two specimens of *G. blattarum* partly embedded in enteric epithelial cells of cockroach; B^1, B^2, two specimens of *G. dujardini*; in B^2 the epimerite (*ep*) is cast off; C, cyst of *G. blattarum*, from which most of the spores have been discharged; D, four stages in the development of *G. gigantea*; *cy*, cyst; *deu*, deutomerite; *ep*, epimerite; *g*, gelatinous investment of cyst; *nu*, nucleus; *pr*, protomerite; *psd. 1*, short pseudopod; *psd. 2*, long pseudopod; *sp*, mass of spores; *spd*, sporoducts. (From Bütschli's *Protozoa*.)

All the Sporozoa are parasitic, and all are characterised by the absence of pseudopodia, flagella, and cilia; and of mouth and gullet, and by the formation of spores enclosed in chitinoid coats. *Gregarina* (Fig. 24) differ from Monocystis in having the medullary part of the protoplasm divided into two sections, known as the *protomerite* (*pr*), and *deutomerite* (*deu*), by a sort of partition, with, in the young condition, a third division, the *epimerite* (*ep*) in front; and in the more complex form of the cysts, which have delicate canals or *sporoducts* (*spd*) through which the spores escape. Some of the Sporozoa (*Coccidium* and others) are parasites, not like Monocystis and Gregarina, in the cavities of organs, but in the interior of cells, such as the cells lining the intestine of higher animals. The various forms of the disease known as malaria in Man have been proved to be due to the presence of a Sporozoan (*Hæmamœba laverani*) which invades and destroys, at a certain stage in its life-history, the red corpuscles of the blood. Another form (*Apiosoma bigeminum*) causes the Texas fever in cattle, the infection being carried by ticks. These parasites cause high fever, anæmia, bloody urine, and the number of red-blood corpuscles is diminished in one week to one-sixth of the normal amount. *Babesia bovis* in the blood of the ox causes the disease known as hæmoglobinurea, and another form produces a similar disease in sheep. A parasite of the tzetse fly, which is a flagellate hæmatozoan, is the cause of the tzetse disease in southern Africa. These organisms live in the marrow and lymphatics, and flush at intervals into the general blood stream. The disease is communicated by the tzetse fly from the wild game, the herds of which are the fester spots which maintain the disease. The silkworm disease called *pebrine* is due to one of the Myxosporidia, *Glugea bombycis*, which inhabits all the tissues of the caterpillar of *Bombyx mori.*

SECTION II. — THE METAZOA

While the Protozoa are predominantly unicellular, and of extremely simple structure, the rest of the animal kingdom, grouped together under the comprehensive title of **Metazoa,** are all multicellular in the adult condition, and have, except in some of the lowest groups, a more or less elaborate structure owing to the presence of complicated systems of organs for carrying on the various functions of animal life. Such an animal as a lobster or a frog, for example, may readily be ascertained to be made up of a complicated system of parts, — skeleton, muscles, digestive organs, blood vessels, and so on, — and it requires only the most superficial microscopic examination of the substance of these various parts to render it evident that each is built up of an immense multitude of cells. A lobster or a frog, however, or any other Metazoan, consists, in the earliest stage of its existence, of a single cell, the **oosperm,** formed by the union of a male cell or *sperm* with a female cell or *ovum.* The ovum (Fig. 25) is usually spherical in shape, with one or more enclosing membranes, with cell-protoplasm enclosing a large nucleus (*germinal vesicle,* as it is often termed in this case), in which are contained one or more small, rounded bodies (*germinal spot* or *spots*). The ovum may contain, in addition to the protoplasm, a quantity of non-protoplasmic material or *yolk.*

Before the changes begin which lead to the formation of the multicellular Metazoan, another cell, the *male cell* or *sperm*, has to unite with the ovum or female cell. Before this takes place, the ovum throws off portions of its substance (Fig. 26, *pol*) in the form of two little rounded bodies — the *polar bodies*. This preliminary process is known as the **maturation** of the ovum. The male cell or sperm is a relatively small cell, usually motile, which penetrates into the ovum, and coalesces with it — the coalescence being what is termed **fertilisation** or **impregnation** — and the immediate result being that, instead of separate ovum and sperm, we have a compound body, the *oosperm*, formed by their union, but not differing at first in any marked degree from the simple ovum, and containing a single nucleus representing both the nucleus of the sperm and that of the ovum.

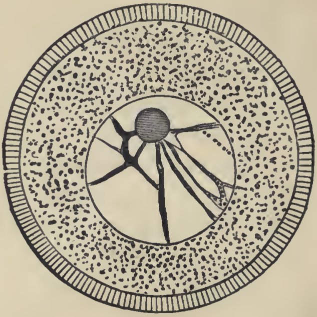
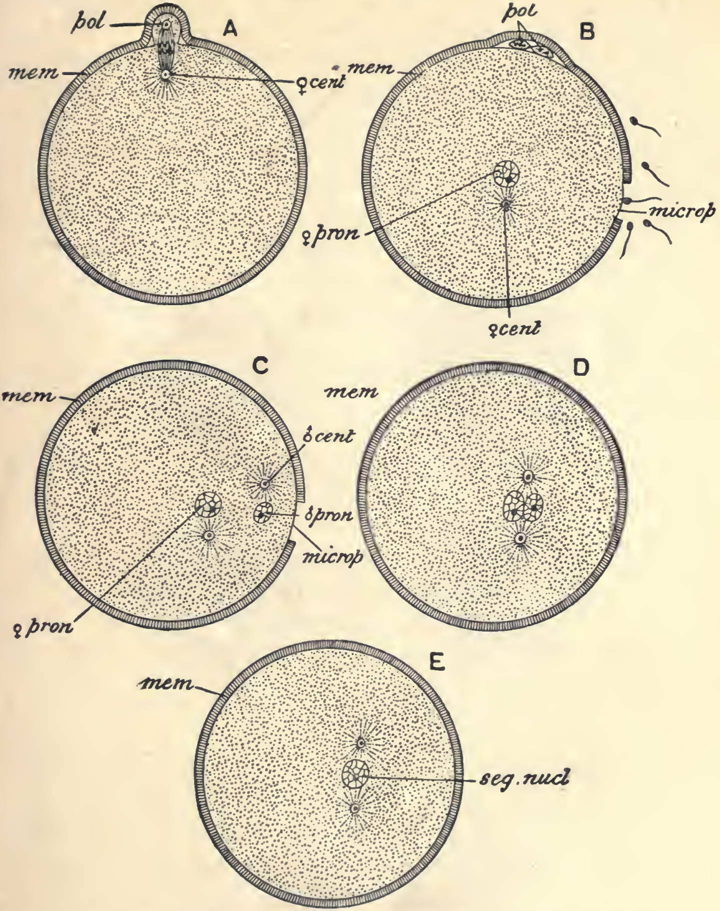


FIG. 25. — Ovum of a Sea-Urchin, showing the radially striated cell-membrane, the protoplasm, containing yolk-granules, the large nucleus (germinal vescicle), with its network of chromatin and a large nucleolus (germinal spot). (From Balfour's *Embryology*, after Hertwig.)

On impregnation follows the process of **segmentation** of the oosperm. The nucleus first divides into two; then the


pol
A
mem
♀cent
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B
mem
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D
mem
E
mem
seg.nucl

FIG. 26. — Diagram illustrating the maturation and fertilisation of the ovum. A, formation of first polar globule; B, beginning of fertilisation, sperms approaching the micropyle or aperture in the enclosing membrane of the ovum through which the sperm enters; C, formation of the male pronucleus; D, approximation of the male and female pronuclei; E, formation of segmentation-nucleus; ♀ *cent*, female centrosome; ♂ *cent*, male centrosome (the centrosomes are cell-structures not further referred to in this work); *mem*, egg-membrane; *microp*, micropyle; *pol*, polar bodies; ♀ *pron*, female pronucleus; ♂ *pron*, male pronucleus; *seg. nucl*, segmentation nucleus.

substance of the protoplasm becomes cleft into two parts (Fig. 27), each half containing one of the nuclei, so that two complete cells result. This process, it will be observed, is essentially the same as the *binary fission* of Amœba and other Protozoa: in the Metazoan, however, the two cells do not become separated from one another as the two parts of the divided Amœba do, but remain in contact and undergo further changes. Each of them divides (Fig. 27) in the same manner into two—four cells being thus formed; the four divide to form eight, the eight to form sixteen, and so on; until, by this process of division and subdivision, the oosperm becomes segmented into a large number of comparatively small cells. In this mass of cells an arrangement into layers, the *germinal layers*, becomes by and by discernible; and from these layers of cells are developed eventually all the parts of the body of the Metazoan.

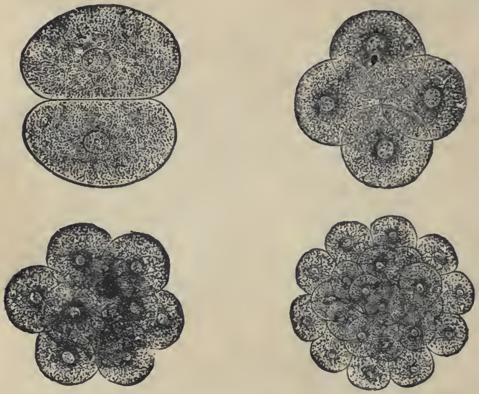

Fig. 27. — Various stages in the segmentation of the oosperm. (From Gegenbaur's *Comparative Anatomy*.)

This mode of development is, however, not entirely without parallel among the Protozoa. In the colonial Volvox (p. 43, Fig. 17) it will be remembered that male cells or microgametes (sperms) and female cells or megagametes (ova) are developed, and that by the coalescence of a microgamete with a megagamete a compound cell, the zygote (oosperm), is formed, which undergoes division to give rise to an adult Volvox.

As the various parts become gradually moulded from the cells of the germinal layers, the form and arrangement of the cells of the different parts become modified in different ways, so that the cellular structure comes to differ widely; and, as a result, we find in the fully formed animal a variety of different kinds of material, — tissues, as they are termed, — such as muscle, bone, gristle, nerve, all derived from the cells of the germinal layers. Of such tissues the following are the most important. An *epithelium* is a thin stratum of cells covering some surface, external or internal; it may be one cell thick, or several cells thick. The cells of which an epithelium is composed vary greatly in form in different cases (Fig. 28): they may be beset at their free surfaces with cilia (*a*), like the cilia of the Infusoria, or with flagella, like those of the Mastigophora (*f*), or may be amœboid (*h*), sending out pseudopodia like a Rhizopod. The epithelium which covers the outer surface is known as the *epidermis* or *deric* epithelium; that which lines the interior of the digestive organs is the *enteric* epithelium.

Glands (Fig. 29) are formed by modification of epithelial cells. In many cases a single cell of the epithelium forms a gland, which is then termed a *unicellular gland* (*A*, *B*). The secretion (or substance which it is the function of the gland to form or collect) gathers in such a case in the interior of the cell, and reaches the surface of the

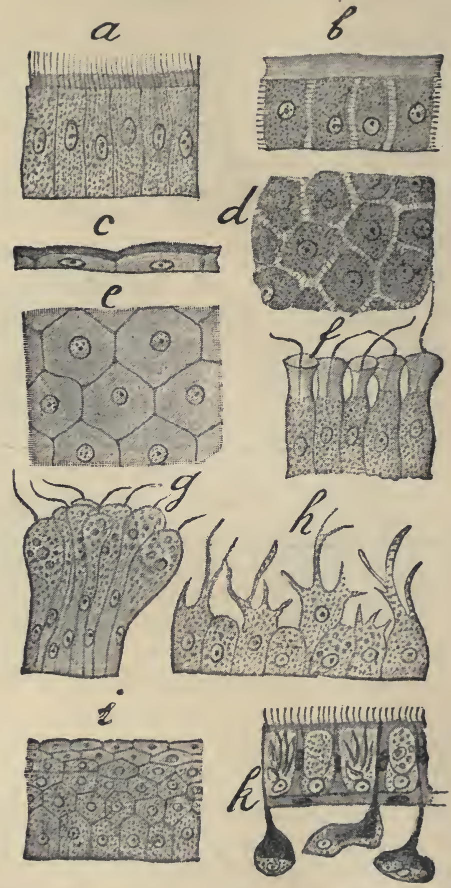

FIG 28. — Various forms of epithelium. *a*, ciliated epithelium; *b*, columnar; *d*, surface view of the same; *c*, tessellated; *e*, the same from the surface; *f*, flagellate epithelium with collars; *g*, flagellate epithelium without collars; *h*, epithelium of intestine with pseudopodia; *i*, stratified epithelium; *k*, deric epithelium of a marine planarian with pigment cells, rod cells, and sub-epithelial glands. (From Lang's *Comparative Anatomy*.)

epithelium through a narrow prolongation of the cell, which serves as the duct of the gland. In other cases the gland is *multicellular* (*D*, *G*), formed of a number of cells of the epithelium, lining a depression or infolding, simple or complex in form, of the latter. In the central cavity of such a gland the secretion collects to reach the surface through a passage, the *duct*.

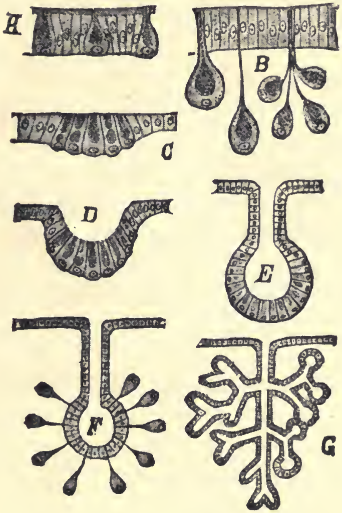

FIG. 29. — Diagram to illustrate the structure of glands. *A*, unicellular glands in an epithelium; *B*, unicellular glands lying below epithelium and communicating with the surface by narrow processes (ducts); *C*, group of gland cells; *D*, group of gland cells lining a depression; *E* and *F*, simple multicellular gland; *G*, branched multicellular gland. (From Lang.)

The general name of *connective tissues* is applied to a number of tissues which play a passive part in the economy of the animal, connecting and supporting or protecting the various organs. Sometimes connective tissue is *gelatinous* in character, sometimes *fibrous*. *Fat* or *adipose tissue* is usually developed by modification of fibrous connective tissue, the cells becoming distended with oily matter. *Cartilage* is a firm but elastic material, readily cut with a knife, which forms an important constituent of the skeleton in higher animals. *Bone* differs from cartilage in being much denser and harder, owing to its being strongly impregnated with limey matter (carbonate and phosphate of lime).

Muscular tissue is the material by means of which nearly all the movements of the Metazoa are effected. It consists of bundles of microscopic fibres, which in the living condition have the special property of *contractility*, contracting, *i.e.* becoming shorter and thicker, when stimulated. Bundles or bands of these form the organs known as muscles. *Nerve tissue*, which is the sensitive, conducting, and stimulating tissue of the body, consists of nerve-cells and nerve-fibres; groups of the former constitute *nerve-ganglia;* bundles of the latter form *nerves*.

Associated with the multicellular character of the Metazoa is the possession of a variety of different parts or **organs** adapted to carrying out different functions in the life of the animal. Such a formation of organs is faintly foreshadowed in the unicellular body of the Protozoa; the contractile vacuoles, the nucleus, the pseudopodia, flagella, and cilia, the gullet, etc., are all to be looked upon as organs subserving certain functions. But in the Metazoa, with the exception of some of the lower groups, the development of organs for the carrying on of the functions of animal life — organs of locomotion, organs for protection and support, organs of digestion, respiration, and reproduction — is carried much further.

Some of the chief functions which are carried on in the body of an animal have already been briefly referred to in the account of the Protozoa. The special study of these constitutes, as already pointed out in the Introduction, the science of Physiology, which forms accordingly an important part of the study of Zoology, and a part to which frequent reference will be made in dealing with the structure of the various groups of animals.

The various internal parts of an animal are supported and protected by the *skin* and the *skeleton*. The skin or integument consists of a layer of cells — the *epidermis* — with, superficial to it, in many animals, a non-cellular layer known as the *cuticle*, and below it usually a fibrous layer, the *dermis*. The skeleton is, as already explained in the section on the Protozoa, a system of hard parts, external or internal, serving for the protection and support of the softer substance of the body. When these hard parts are external they form an *exoskeleton*, when internal an *endoskeleton*. An exoskeleton is formed by the thickening and hardening of portions of one or other of the layers of the integument, — cuticle, epidermis, or dermis. An endoskeleton usually

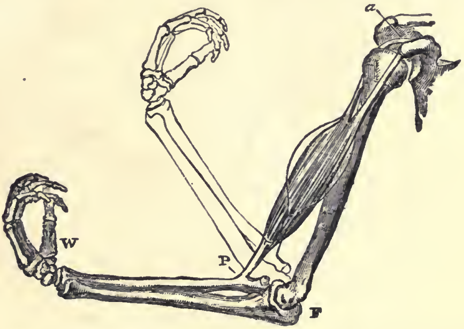

FIG. 30. — Bones of the human arm and fore-arm with the biceps muscle, showing the shortening and thickening of the muscle during contraction and the consequent change in the relative position of the bones — viz., flexion of the fore-arm on the upper arm. (From Huxley's *Physiology*.)

consists either of cartilage, or of bone, or of both. The parts of the skeleton in the higher animals, whether external or internal, usually consist of a number of distinct pieces which are movably articulated together, and these have the additional important function of serving for the attachment of muscles, constituting a jointed framework on which the muscles act in bringing about the various movements of the body and its appendages (Fig. 30).

The nutrition of the Metazoa is in some cases, as in some of the Protozoa, effected by food being absorbed in a dissolved form through the general surface. In the great majority, however, the food, liquid or solid, is received through an opening — the mouth — into a cavity in the interior of the body — the *digestive* or *enteric* cavity. In most cases this has the form of a longer or shorter tube or canal, beginning at the mouth and ending at a second external opening — the *anus*. This digestive or enteric canal consists usually of a number of different parts, through which the food passes in succession, each part having its special function to perform in connection with nutrition. In most cases there are organs in the neighbourhood of the mouth serving for the seizure of food ; these may be simply *tentacles*, or soft, finger-like appendages, or they may have the form of *jaws*, by means of which the food is not only seized but torn to pieces, or ground into small fragments, in the process of *mastication*. In general we can distinguish in the enteric canal a *buccal cavity*, a *pharynx*, an *œsophagus* or *gullet*, a *stomach*, and an *intestine*. It is in the stomach and anterior part of the intestine that the food becomes acted upon by certain digestive secretions, the effect of which is to render the various ingredients soluble, and thus fitted to be absorbed through the wall of the enteric canal, so as to reach the various parts of the body and supply them with nourishment. These digestive secretions are partly produced by the cells of the epithelium of the canal, which are modified to form unicellular or multicellular glands (p. 65), partly by certain large special digestive glands, *salivary glands*, *liver*, and *pancreas*. The nutrient parts of the food are by this means so acted upon that they are ready to be absorbed, and in most animals pass into the blood, to be distributed throughout the body. The insoluble and indigestible ingredients of the food pass on through the posterior part of the intestine, and reach the exterior through the anal aperture as the *fæces*.

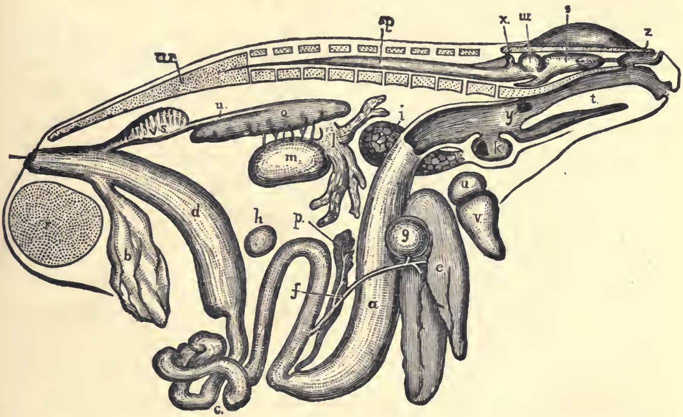

FIG. 31.—General view of the viscera of a male frog, from the right side. *a*, stomach; *b*, urinary bladder; *c*, small intestine; *cl*, cloacal aperture; *d*, large intestine; *e*, liver; *f*, bile duct; *g*, gall bladder; *h*, spleen; *i*, lung; *k*, larynx; *l*, fat body; *m*, testis; *n*, ureter; *o*, kidney; *p*, pancreas; *s*, cerebral hemisphere; *sp*, spinal cord; *t*, tongue; *u*, auricle; *ur*, urostyle; *v*, ventricle; *v.s*, vesicula seminalis; *w*, optic lobe; *x*, cerebellum; *y*, Eustachian recess; *z*, nasal sac. (From Marshall.)

A supply of oxygen is necessary for the carrying on of the chemical changes in the tissues on which vital activity is dependent. At the same time, as a result of these changes, carbonic anhydride (carbonic acid gas) is constantly being produced. The taking in of oxygen and giving off of carbonic anhydride is the process of respiration. The task of facilitating the entry of oxygen and the passage outwards of carbonic anhydride is in most of the Metazoa performed by a set of organs known as *organs of respiration;* but in many respiration takes place through the general surface, and special organs for carrying on this function are absent. When organs of respiration are present, they are either processes or *gills* (*branchiæ*) adapted for the respiration of air dissolved in water; or *lungs* or other cavities which are adapted for the direct respiration of air. Through the thin membrane lining the gill, or lungs, the oxygen passes and enters the blood in vessels immediately underneath the membrane, to be conveyed, like the food, throughout the system and supplied to the several parts. At the same time the carbonic anhydride, brought to the gill or lung by the same means, passes outwards into the surrounding water or air, and is thus got rid of.

The blood consists of a fluid *plasma*, in which float numerous cells — the *blood corpuscles*. Sometimes the blood is colourless; usually it is bright red, owing to the presence of a red colouring matter, termed *hæmoglobin*, which is sometimes confined to certain of the corpuscles, sometimes diffused throughout the plasma. Hæmoglobin has a strong affinity for oxygen, and is thus of importance in connection with respiration.

In order to carry on its functions as a conveyer of nutriment and of oxygen throughout the body, the blood flows in a system of *vessels* — the *blood vascular system* — which ramify throughout all the organs. Through this system of vessels it is driven in a more or less regular course, either by pulsating contractions of the muscular walls of the blood-vessels themselves, or by the agency of a special organ, the *heart*. The heart is essentially a sac with muscular walls. Its cavity is in communication with the main blood-vessels, and its walls contract regularly and drive the blood through the system of vessels, the direction of flow being regulated by a system of valves.

The nitrogenous waste-matters which are produced as a result of the chemical changes that accompany vital action in the various organs, are separated out and got rid of by a system of organs known as the *organs of excretion*, or *renal organs* — this process of elimination being known as the process of *renal excretion*.

It is by means of the *nervous system* that the animal receives impressions from the exterior and from the internal organs, and that the various internal parts are brought into vital communication with one another. The nervous system extends as a complicated system of nerves or bundles of nerve-fibres throughout all parts of the body. Large aggregations of nerve-cells and nerve-fibres forming the centres of the system are known as nerve-ganglia. When one of these, or a group of them, situated towards the anterior end, preponderates in size over the others, it is termed the *brain*. Forming an important part of the nervous system are the organs of the special senses, — sight, hearing, smell, and taste, each of which is an organ adapted for the reception of impressions of a special kind from the exterior, — the impressions of light, of sound waves, of the particles and substances that produce the sensations of smell and taste. The less specialised sense of touch and of heat and cold is diffused generally over the integument, in which there are frequently special cells, or groups of cells, with nerve-fibres terminating in them, that are concerned with such sensations.

The organs of sexual reproduction are the *gonads*, in which male and female cells or sperms and ova are produced, with the *gonoducts* or canals by which these cells reach the exterior. The gonads in which male cells or sperms are produced are called *testes*, and their ducts are the *sperm-ducts*. The gonads in which female cells or ova are formed are called *ovaries*, and their ducts *oviducts*. Sometimes testes and ovaries occur in distinct *male* and *female* individuals, when the animal is said to be unisexual, or to have the sexes distinct. In other cases both ovaries and testes occur in the same individual, when the animal is said to be *hermaphrodite*, or to have the sexes united. In some instances the same gonad produces both sperms and ova—assuming the character of a hermaphrodite gonad or ovo-testis.

In many animals the ova are fertilised by the sperms after they have passed out from the body, and the development takes place externally—a condition which is known as *oviparity*. But in others the ova are fertilised while still in the ovary or oviduct of the parent, and the development may take place in the oviduct, usually in a special dilated part of the latter—the *uterus*—so that the young only escape to the exterior after they have attained a comparatively advanced stage of their development—when the animal is said to be *viviparous*.

Besides the sexual process of reproduction by means of ova and sperms, there are in many classes of animals various *asexual* modes of multiplication. One of these—the process of *simple fission*—has been already noticed in connection with the reproduction of Protozoa. The formation of *spores* is an asexual mode of multiplication which occurs only in the Protozoa, and has been described in the account of that group. Multiplication by *budding* takes place in a number of different classes of animals. In this form of reproduction a process or *bud* (Fig. 32, *bd*) is given off from some part of the parent animal; this bud sooner or later assumes the form of the complete animal, and may become detached from the parent either before or after its development has been completed, or may remain in permanent vital connection with it.

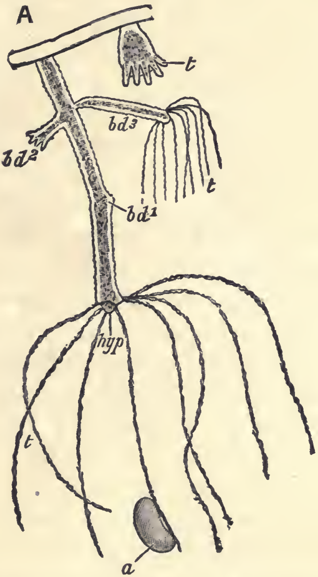

Fig. 32. — Fresh-water polype (hydra), two specimens, the one expanded the other contracted, showing multiplication by budding. *bd*1 *bd*2 *bd*3, buds in various stages of growth. (From Parker's *Biology*.)

When the buds, after becoming fully developed, remain in vital continuity with the parent, a sort of compound animal, consisting of a greater or smaller number of connected units, is the result. Such a compound organism is termed a *colony*, and the component units are termed *zooids*. In some cases such a colony is produced by a process which is more correctly termed *incomplete fission* than budding.

The various systems of organs, — digestive, circulatory, nervous, excretory, etc., — present under one form or another in all the higher groups of animals, are variously arranged and occupy various relative positions in different cases, producing a number of widely different plans of animal structure. According as their structure conforms to one or another of these great plans, animals are referred to one or another of the corresponding great divisions or *phyla* of the animal kingdom. That animals do present widely differing plans of structure is a matter of common knowledge. We have only to compare the true fish, such as cod, haddock, etc., in a fishdealer's shop with the lobsters and the oysters, to recognise the general nature of such a distinction. The first named are characterised by the possession of a backbone and skull, with a brain and spinal cord, and of two pairs of limbs (the paired fins): they belong to the great vertebrate or backboned group — the division *Vertebrata* of the phylum *Chordata*. The lobsters, on the other hand, in which these special vertebrate structures are absent, possess a jointed body enclosed in a hard jointed case, and a number of pairs of limbs also enclosed in hard jointed cases, and adapted to different purposes in different parts of the body — some being feelers, others jaws, others legs: their general type of structure is that which characterises the phylum *Arthropoda*. The oysters, again, with their hard calcareous shell secreted by a pair of special folds of the skin constituting what is termed the *mantle*, and with a special arrangement of the nervous system and other organs which need not be described here, are referable to the phylum *Mollusca*. Other familiar animals are readily to be recognised as belonging to one or other of these great phyla. A prawn, a crab, a bluebottle fly, a spider, are all on the same general plan as the lobster: they are jointed animals with jointed limbs, and they have the internal organs occupying similar positions with relation to one another. They are all members of the phylum *Arthropoda*. Again, a mussel, a snail, a squid, are all to be set side by side with the oyster as conforming to the same general type of structure; they are all members of the phylum *Mollusca*. Finally a dog, a lizard, a fowl, are obviously nearer the fish: they all have skull and backbone, brain and spinal cord, and two pairs of limbs; they are all members of the great group *Chordata*.

Altogether twelve phyla are to be recognised, viz.:—

I. *Protozoa* ✓
II. *Porifera* ✓
III. *Cœlenterata* ✓
IV. *Platyhelminthes*
V. *Nemathelminthes* ✓
VI. *Trochelminthes*
VII. *Molluscoida*
VIII. *Echinodermata* ✓
IX. *Annulata* ✓
X. *Arthropoda* ✓ lobsters
XI. *Mollusca* ✓ oysters
XII. *Chordata*

SECTION III. — PHYLUM PORIFERA

THE **Porifera,** or sponges, belong to the lowest group of the Metazoa. They live fixed to the surface of rocks, or to submerged timber or seaweeds, so as to be incapable of locomotion; and have, in most cases, a general form which suggests the vegetable rather than the animal kingdom. But, in essentials, as will presently become evident, the sponges are distinctly animal in character, and the resemblances to plants are entirely superficial.

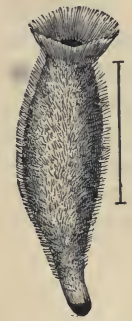

FIG. 33.—**Sycon ciliatum.** (After Hyatt.) *Riverside Nat. His.*

The majority of sponges are complicated and difficult to understand, owing to their elaborate mode of branching and the fusion of the branches, and to the exceedingly intricate character of the skeletal parts, aside from their cellular structure. Some, however, are free from these complications; and it is in one of these that the main characteristics of sponges are best studied. Such a simple form is **Sycon,** a small sponge living attached to rocks on the seashore towards or below low-water mark. *Sycon gelatinosum*[1] has the form of a tuft, one to three inches long, of branching cylinders (Fig. 34), all connected together at the base, where it is attached to the surface of seaweeds, rocks, or other solid bodies submerged in the sea. It is flexible, though of tolerably firm consistency. On the outer surface are to be detected, under the microscope, groups of minute pores — the *inhalant pores*. At the free end of each of the cylindrical branches is a small but distinct opening, surrounded by what appears like a delicate fringe. When the branches are bisected longitudinally (Fig. 35), it is found that the terminal openings (*o*) lead into narrow passages, wide enough to admit a stout pin, running through the axis of the cylinders; and the passages in the interior of the various branches join where the branches join — the passages thus forming a communicating system. On the wall of the passages are numerous fine apertures which require a strong lens for their detection. The larger apertures at the ends of the branches are the *oscula* of the sponge, the passages the *paragastric cavities*. If the living Sycon is placed in sea-water with which has been mixed some carmine powder, it will be noticed that the minute particles of the carmine seem to be attracted towards the surface of the

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[1] This is an Australasian species, but the following account will apply in all essential respects to *Sycon ciliatum* (Fig. 33) and *S. clarkii* of the coast of New England.

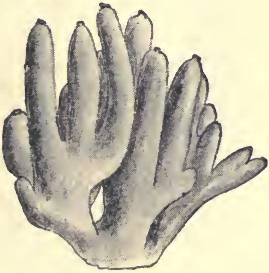

FIG. 34. — **Sycon gelatinosum.** Entire sponge, consisting of a group of branching cylinders (natural size).

sponge, and will often be seen to pass into its substance through the minute pores already mentioned as occurring in groups between the elevations on the outer surface. This would appear to be due to the passage of a current of water into the interior of the sponge through these minute openings dotted over the surface; and the movement of the floating particles shows that a current is at the same time flowing out of each of the oscula. A constant circulation of

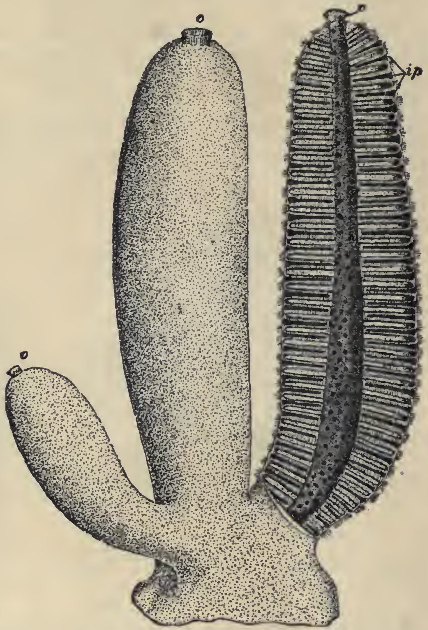

FIG. 35.—**Sycon gelatinosum.** A portion slightly magnified; one cylinder (that to the right) bisected longitudinally to show the central paragastric cavity opening on the exterior by the osculum, and the position of the incurrent and radial canals; the former indicated by the black bands, the latter dotted. *ip* marks the position of three of the groups of inhalant pores at the outer ends of the incurrent canals; *o*, osculum.

water would thus appear to be carried on — currents moved by some invisible agency flowing through the walls of the sponge to the central paragastric cavities, and passing out again by the oscula.

If a portion of the Sycon is firmly squeezed, there will be pressed out from it first sea-water, then, when greater pressure is exerted, a quantity of gelatinous-looking matter, which, on being examined microscopically, proves to be partly composed of a protoplasmic material consisting of innumerable, usually more or less broken, cells with their nuclei, and partly of a non-protoplasmic, jelly-like substance. When this is all removed there remains behind a toughish, felt-like material, which maintains more or less completely the original shape of the sponge. This is the *skeleton* or supporting framework. A drop of acid causes it to dissolve with effervescence, showing that it consists of carbonate of lime. When some of it is teased out and examined under the microscope, it proves to consist of innumerable, slender, mostly three-rayed microscopic bodies (Fig. 36, *sp*) of a clear, glassy appearance. These are the *calcareous spicules* which form the skeleton of the Sycon.

Covering the outer surface of the sponge is a single layer of flattened, scale-like cells — the *ectoderm* (Fig. 36, *ec*) — through which project regularly arranged groups of needle-like and spear-like spicules (*sp'*). The paragastric cavities are lined by a layer of cells (*en*), which are like those of the ectoderm in general shape; this is the *endoderm* of the paragastric cavity. Running radially through the thick wall of the cylinders are a large number of regularly arranged straight passages. Of these there are two sets, those of the one set — the *incurrent canals* (*IC*) — narrower, and lined by ectoderm similar to the ectoderm of the surface; those of the other set — the *radial* or

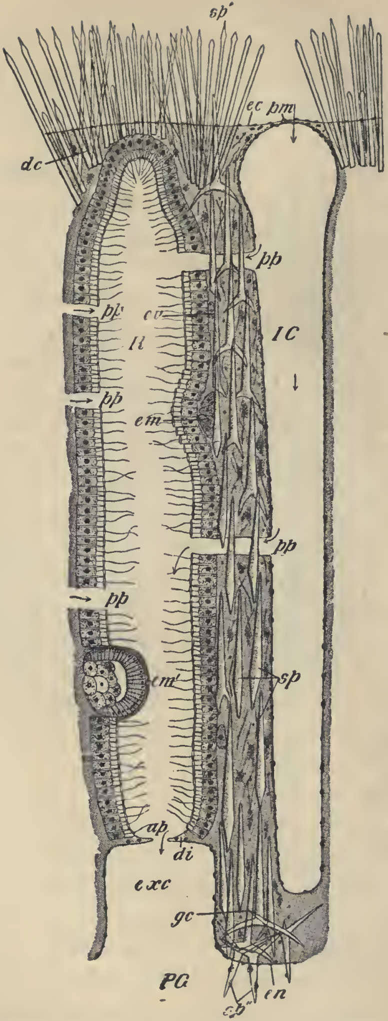

FIG. 36. — **Sycon gelatinosum.** Transverse section through the wall of a cylinder (parallel with the course of the canals), showing one incurrent canal (*IC*), and one radial (*R*) throughout their length; *sp*, triradiate spicules; *sp'*, oxeote spicules of dermal cortex (*dc*); *sp''*, tetraradiate spicules of gastral cortex (*gc*); *ec*, ectoderm; *en*, endoderm; *pm*, pore membrane; *pp*, prosopyles; *ap*, apopyle; *di*, diaphragm; *exc*, excurrent passage; *PG*, paragastric cavity; *em*, early embryo; *em'*, late embryo. The arrows indicate the course of the water through the sponge.

flagellate canals (*R*) — rather wider, octagonal in cross-section, and lined by endoderm continuous with the lining of the paragastric cavity. The incurrent canals end blindly at their inner extremities, not reaching the paragastric cavity; externally each becomes somewhat dilated, and the dilations of neighbouring canals often communicate. These dilated parts are closed externally by a thin membrane — the *pore membrane*, perforated by three or four openings — the inhalant pores already referred to. The flagellate canals are blind at their *outer* ends, which lie at a little distance below the surface; internally, each communicates with the paragastric cavity by a short, wide passage, the *excurrent canal* (*exc*). Incurrent and flagellate canals run side by side, separated by a thin layer of sponge substance, except at certain points, where there exist small apertures of communication — the *prosopyles* (*pp*) — uniting the cavities of adjacent incurrent flagellate canals.

The ectoderm lining of the incurrent canals is of the same character as the ectoderm of the outer surface. The endoderm (*R*) of the flagellate canals, on the other hand, is totally different from that which lines the paragastric cavity. It consists of cells of columnar shape, ranged closely together so as to form a continuous layer. Each of these *flagellate endoderm cells*, or *collared cells*, as they are termed, is not unlike one of the choanoflagellate Protozoa (p. 38); it has its nucleus, one or more vacuoles, and, at the inner end, a single, long, whip-like flagellum, surrounded at its base by a delicate, transparent, collar-like upgrowth, similar to that which has already been described as occurring in the Choanoflagellata. If a portion of a living specimen of the sponge is teased out in sea-water, and the broken fragments examined under a tolerably high power of the microscope, groups of these collared cells will be detected here and there, and in many places the movements of the flagella will be readily observed. It is to these movements that the formation of the currents of water passing along the canals is due.

The short passage or excurrent canal, which leads inwards from the flagellate canal to the paragastric cavity, differs from the former in being lined by flattened cells similar to those of the paragastric cavity; it is partly separated from the flagellate canal by a thin diaphragm (Fig. 36, *di*), perforated by a large circular central aperture — the *apopyle* (*ap*) — which is capable of being contracted or dilated; its opposite aperture of communication with the paragastric cavity, which is very wide, is termed the *gastric ostium* of the excurrent canal.

The effect of the movement of the flagella of the cells in the flagellate canals is to produce currents of water running from without inwards along the canals to the paragastric cavity. This causes water to be drawn inwards through the prosopyles from the incurrent canals, and, indirectly, from the exterior through the perforated membranes at the outer ends of the latter.

Between the ectoderm of the outer surface and of the incurrent canals, and the endoderm of the inner surface and of the flagellate canals, are a number of spaces filled by an intermediate layer — the *mesoderm* or *mesoglœa* — in which the spicules of the skeleton are embedded. The spicules (Fig. 36, *sp.*), each of which is developed in a single cell of the middle layer, are regularly arranged, and connected together in such a way as to protect and support the soft parts of the sponge. Most are, as already noticed, of triradiate form. Large numbers, however, are of simple spear-like or club-like shape (*sp'*). The sexual reproductive cells — the *ova* (Fig. 36, *ov*) and *sperms* — are developed immediately below the flagellate endoderm cells of the flagellate canals, and in the same situation are to be found developing embryos (*em*, *em'*).

The simplest **sponges** are vase-shaped or cylindrical in form, either branched or unbranched, and, if branched, with or without anastomosis or coalescence between neighbouring branches. But the general form of the less simple sponges differs widely from that of such a branching cylinder as is presented by Sycon (Fig. 34).

From the point to which the embryonic sponge becomes attached, it may spread out horizontally, following the irregularities of the surface on which it grows, and forming a more or less closely adherent encrustation like that of an encrusting lichen. In other cases the sponge grows at first more actively in the vertical than in the horizontal direction, and the result may be a long, narrow structure, cylindrical or compressed, and more or less branched. Sometimes vertical and horizontal growth is almost equal, so that eventually there is formed a thick, solid mass of a rounded or polyhedral shape, with an even, or lobed, or ridged surface. Very often, after active vertical growth has resulted in the formation of a comparatively narrow basal part or stalk, the sponge expands distally, growing out into lobes or branches of varying forms, and frequently anastomosing. Sometimes after the formation of the stalk with root-like processes for attachment, the sponge grows upwards in such a way as to form a cup or tube with a terminal opening. Sometimes the sponge grows from a narrow base of attachment into a thin flat plate or lamella; this may become divided up into a number of parts or lobes, which may exhibit a divergent arrangement like the ribs of an open fan.

Sycon belongs to a type of sponges intermediate between the very simplest forms on the one hand, and the more complex on the other. The simplest and most primitive of known sponges is one named **Ascetta primordialis** (Fig. 37). It is vase-shaped, contracted at the base to form a sort of stalk, by the expanded extremity of which it is attached; at the opposite or free end is the circular osculum. So far there is a considerable resemblance to *Sycon gelatinosum;* but the structure of the wall in Ascetta is extremely simple. Regularly arranged over the surface are a number of small rounded apertures, the inhalant or incurrent pores; but, since the wall of the sponge is very thin, these apertures lead directly into the central or paragastric cavity, the long passages or canals through which the communication is effected in Sycon being absent. The wall consists of the same three layers as in Sycon; but the middle one, though it contains a small number of spicules, is very thin; the endoderm, which lines the

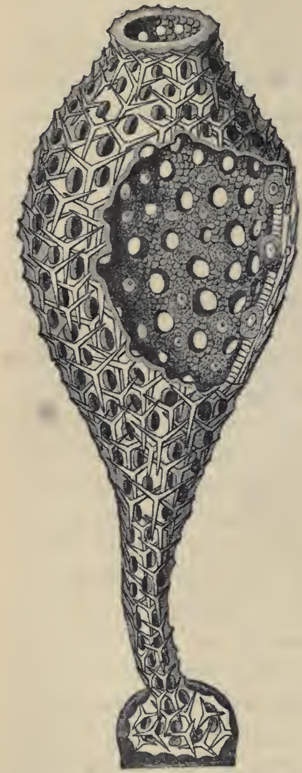

Fig. 37.—**Ascetta primordialis.** A portion of the wall of the vase-like sponge removed to show the paragastric cavity. (After Haeckel.)

paragastric cavity, consists throughout of flagellate collared cells similar to those of the flagellate canals of Sycon.

The majority of sponges, however, are more complicated in structure than Sycon. One of the causes of their complexity being that the canals, instead of being simple and straight, become branched, forming a system, often highly complicated, of ramifying channels. In these more complex sponges the flagellate collared cells are confined to certain rounded dilatations of the canals — the *flagellate chambers.*

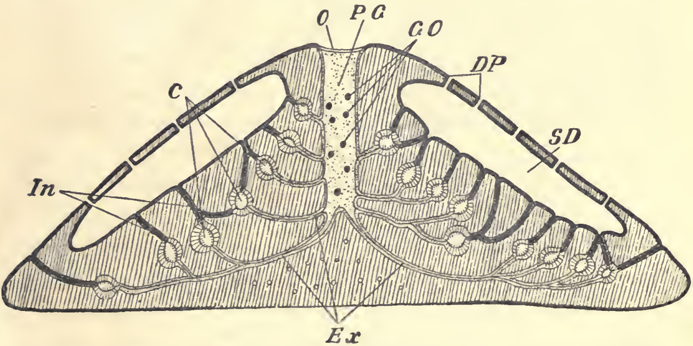

FIG. 38. — Vertical section of a fresh-water sponge (**Spongilla**), showing the arrangement of the canal-system. *C*, ciliated chambers; *DP*, dermal pores; *Ex*, excurrent canals; *GO*, openings of the excurrent canals; *PG*, paragastric cavity; *SD*, subdermal cavities; *O*, osculum. (Modified from Leuckart and Nitsche's diagrams.)

Moreover, in the more complex forms the development of branches from the originally simple sponge, and the coalescence of neighbouring branches with one another, greatly obscure the essential nature of the sponge as a colony of zooids similar to the branches of Sycon; and this effect is increased by the development of a variety of infoldings of the ectoderm which appear in the higher forms.

The elements of the *skeleton* differ in character in the two sub-classes into which the sponges are divided. In the **Calcarea**, of which Sycon is an example, they consist of *calcareous spicules*, usually triradiate in form. In the **Non-Calcarea** the skeleton either consists of *spongin fibres* alone (Fig. 39, *A*), or of *siliceous spicules* alone, or of a combination of spongin fibres with siliceous spicules (*B*): in some (**Myxospongiæ**) skeletal parts are altogether absent. Spongin is a substance allied to silk in composition; the fibres are exceedingly fine threads, which branch and anastomose, or are woven and felted together in such a way as to form a firm, elastic supporting structure. The siliceous spicules (Fig. 40) are much more varied in shape than the spicules of the Calcarea, and in a single kind of sponge there may be a number of widely differing forms of spicules, each form having its special place in the skeleton of the various parts of the sponge-body. In most Non-Calcarea siliceous spicules and spongin fibres combine to form the supporting framework, the relative development of these two elements varying greatly in different cases. But in certain groups of the Non-Calcarea, including the common washing sponges, spicules are completely absent, and the entire skeleton consists of spongin. In some Non-Calcarea which are devoid of spicules, the place of these is taken by foreign bodies — shells of Radiolaria, grains of sand, or spicules from other sponges (Fig. 39, *C*). In others, again, such as the Venus's flower-basket (*Euplectella*), the glass-rope sponge (*Hyalonema*), and others, the skeleton consists throughout of siliceous spicules bound together by a siliceous cement.

Reproduction in the Sponges is effected either sexually or asexually. The process by which, in all but the simplest forms of sponges, a colony of zooids is formed from the originally simple cylinder or vase, may be looked upon as an asexual mode of reproduction by budding. Asexual

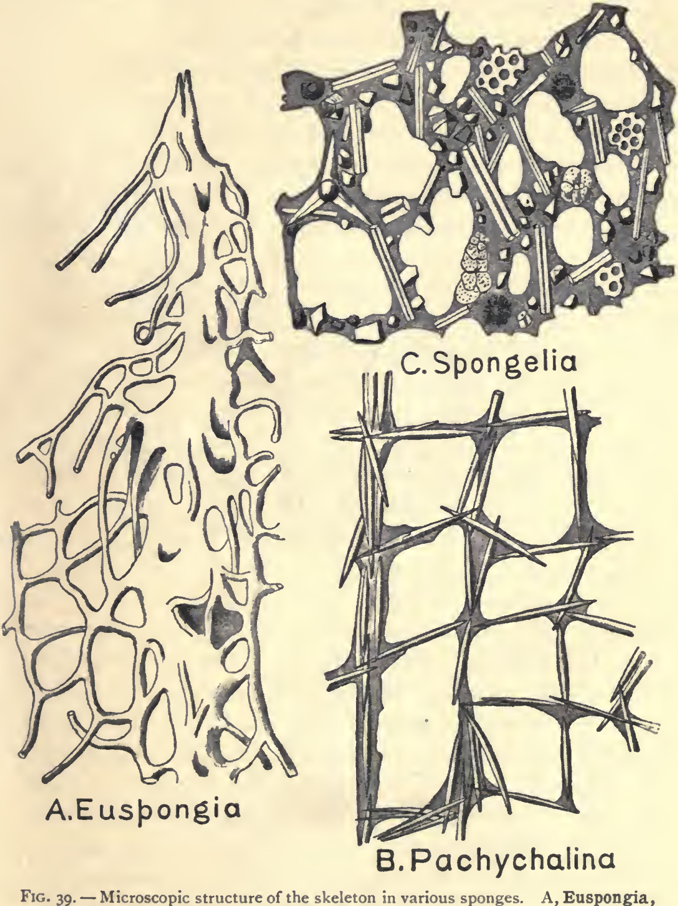

FIG. 39. — Microscopic structure of the skeleton in various sponges. A, **Euspongia,** network of spongin fibres; B, **Pachychalina,** spongin strengthened by siliceous spicules; C, **Spongelia,** spongin strengthened by various foreign siliceous bodies, fragments of spicules of other sponges, etc. (After Vosmaer.)

multiplication also assumes the form in some cases of a process of production of internal buds in the shape of groups of cells called *gemmules*, which eventually become detached and develop into new individuals. In the fresh-water sponges (*Spongillidæ*) multiplication takes place very actively by means of such gemmules, each of which is a spherical group of cells enclosed in an envelope composed of peculiarly shaped siliceous spicules, termed *amphidiscs* (Fig. 40, right side). All sponges multiply by a sexual process — by means of male cells, or *sperms*, and female cells, or *ova*. Ova and sperms are developed in the same sponge, but rarely at the same time. The cell destined to form sperms divides into a number of small cells, giving rise to a rounded mass of sperms. The latter, when mature, have oval or pear-shaped heads and a long tapering appendage or tail. Each cell destined to form an ovum enlarges, and eventually assumes a spherical form. After a sperm has penetrated into its interior and effected impregnation, it usually becomes enclosed in a brood-capsule formed for it by certain neighbouring cells, and in this situation, still enclosed in the parent sponge, it undergoes

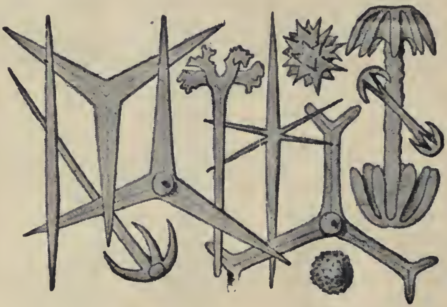

FIG. 40. — Various forms of sponge spicules. (From Lang's *Text-Book*.)

the earlier stages of its development. Eventually it becomes free as a ciliated larva, which pursues a free existence for a time, swimming about by the agency of the cilia, till after a time it becomes fixed and develops into the adult form.

Fresh-water sponges (*Spongillidæ*) live in rivers, lakes, etc. Marine sponges occur in all seas, and at all depths, from the shore between tide marks to the deepest abysses of the ocean.

Sponges do not appear to be edible by fishes, or even the higher crustaceans or molluscs. Countless lower animal forms, however, burrow in their substance, if not for food, at least for shelter, and the interior of a sponge is frequently found to be teeming with small crustaceans, annelids, molluscs, and other invertebrates. None of the sponges are true parasites. The little boring sponge, *Cliona*, burrows in the shells of oysters and other bivalves, and even into solid limestone, but for protection and not for food. But the sponge frequently lives in that close association with another animal or plant to which the term *messmateism*, or commensalism is applied — associations which benefit one or both. Thus some species of sponge are never found growing except on the backs or legs of certain crabs. In these cases the sponge protects the crab and conceals it from its enemies, while the sponge benefits by being carried from place to place, and thus obtaining freer oxygenation. Certain cirripede crustaceans (members of the order to which the barnacles and acorn-shells belong) are invariably found embedded in certain species of sponge. Frequently a sponge and a zoophyte grow in intimate association, so that they seem almost to form one structure. Thus the glass-rope sponge (*Hyalonema*) is always found associated with a zoophyte (*Palythoa*), and there are many other instances. Sponges often also grow in very close association with certain low forms of plants (*Algæ*).

SECTION IV.—PHYLUM CŒLENTERATA

In the previous section we saw that the simplest type of sponge has the general character of a cylinder, closed at one end and open at the other, and having the walls perforated by minute pores, and composed of three layers,—ectoderm, mesoglœa, and endoderm, the last consisting of collared flagellate cells.

In such an organism as this, imagine the pores to disappear, the internal cavity thus coming to communicate with the exterior by a single terminal aperture; the mesoglœa to be replaced by a very thin, structureless layer containing no cells; the endoderm cells to lose their collars; and a circlet of arm-like processes, or tentacles, formed of the same layers as the body-wall, to be developed round the terminal aperture. The result would be a *polype*, and would serve as a type of the general structure of the group of animals with which we are now concerned.

The most familiar examples of Cœlenterata are the horny, seaweed-like hydroids, or, as they are sometimes called, "zoophytes," to be picked up on every sea-beach, jellyfishes, sea anemones, and corals. The phylum is divided into four classes as follows:—

Class 1.—**Hydrozoa,** including the fresh-water polypes, zoophytes, many jellyfishes,—mostly of small size,—and a few stony corals.

Class 2. — **Scyphozoa,** including most of the large jellyfishes.

Class 3. — **Actinozoa,** including the sea-anemones, and the vast majority of stony corals.

Class 4. — **Ctenophora,** including certain peculiar jellyfishes known as "comb-jellies."

1. THE HYDROZOA

Obelia, which is a good example of the class, is a common zoophyte occurring in the form of a delicate, whitish, or light brown, almost fur-like growth on the wooden piles of piers and wharfs. *Obelia commissuralis* occurs on the coast of New England almost at low-water mark, being exposed only at the lowest tides. With it, north of Cape Cod, may be found *Obelia gelatinosa*, a rather stouter species, but similar in general appearance. *Obelia geniculata* is abundant on Laminaria or the "devil's apron," giving the fronds when submerged a downy appearance. The following account refers to a common European species: It consists of branched filaments about the thickness of fine sewing cotton; of these, some are closely adherent to the timber, and serve for attachment, while others are given off at right angles, and present at intervals short lateral branches, each terminating in a bud-like enlargement. The structure is best seen under a low power of the microscope. The organism (Fig. 41) is a colony, consisting of a common stem or axis, on which are borne numerous zooids.

The large majority of the zooids have the form of little conical structures (*P, 1–P, 4*), each enclosed in a glassy, cup-like investment or *hydrotheca* (*hth*), and produced distally into about two dozen arms or *tentacles* (*t*): these zooids are the *polypes* or *hydranths*. Less numerous, and found chiefly towards the proximal region of the colony, are long cylindrical bodies or *blastostyles* (*bls*), each enclosed in a transparent case, the *gonangium* or *gonotheca* (*gth*), and bearing numerous small lateral offshoots, varying greatly in form according to their stage of development, and known as *medusa-buds* (*m.bd*). By studying the development of these structures, and by a comparison with other forms, it is known that both blastostyles and medusa-buds are zooids, so that the colony is *trimorphic*, having zooids of three kinds.

To make out the structure in greater detail, living specimens should be observed under a high power. A polype is then seen to consist of a somewhat cylindrical, hollow *body*, of a yellowish colour, joined to the common stem by its proximal end and produced at its distal end into a conical elevation, the *manubrium* or *hypostome* (*mnb*), around the base of which are arranged the twenty-four tentacles in a circle. Both body and manubrium are hollow, containing a spacious cavity, the *enteron* (*ent*), which communicates with the outer world by a *mouth* (*mth*), an aperture placed at the summit of the manubrium. The mouth is capable of great dilatation and contraction, and accordingly the manubrium appears now conical, now trumpet-shaped. Under favourable circumstances small organisms may be seen to be caught by the tentacles and carried towards the mouth to be swallowed. The hydrotheca (*hth*) has the form of a vase or wine-glass, and is perfectly transparent and colourless. When irritated — by a touch, or by the addition of alcohol or other poison — the polype undergoes a very marked contraction: it suddenly withdraws itself more or less completely into the theca, and the tentacles become greatly shortened and curved over the manubrium (*P. 2*).

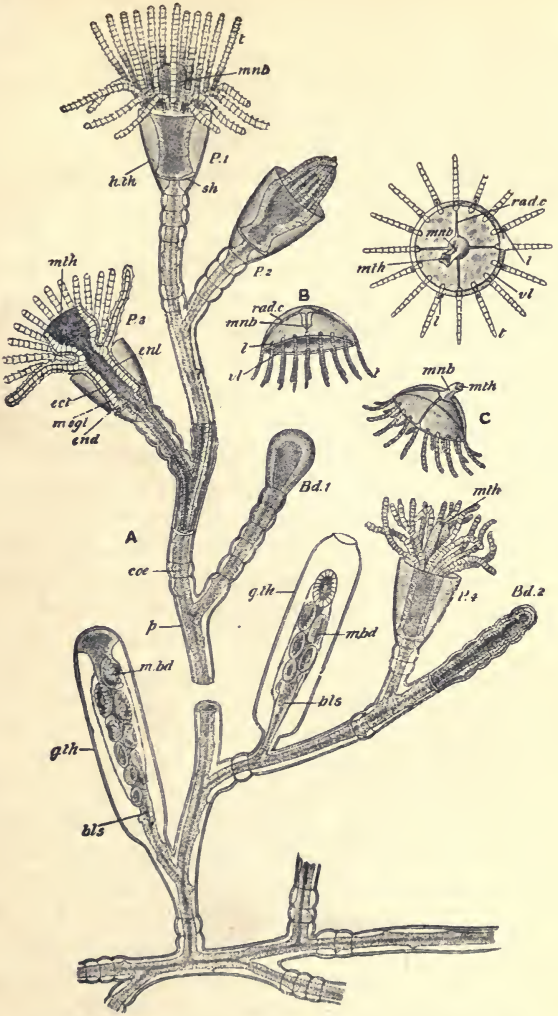
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Fig. 41. — **Obelia sp.** A, portion of a colony, with certain parts shown in longitudinal section; B, medusa; C, the same, with reversed umbrella; D, the same, oral aspect; *Bd. 1, 2*, buds; *bls*, blastostyle; *cœ*, cœnosarc; *ect*, ectoderm; *end*, endoderm; *ent*, enteric cavity; *gth*, gonotheca (gonangium): *hth*, hydrotheca; *l*, lithocyst; *m.bd*, medusa-bud: *mnb*, manubrium; *msgl*, mesoglœa; *mth*, mouth: *p*, perisarc; *P. 1, 2, 3, 4*, polypes; *rad. c*, radial canal; *t*, tentacle; *vl*, velum.

The various branches of the common stem show a very obvious distinction into two layers: a transparent, tough, outer membrane, of a yellowish colour and horny consistency, the *perisarc* (*p*), and an inner, delicate, granular layer, the *cœnosarc* (*cœ*), continuous by a sort of neck or constriction with the body of each hydranth. The cœnosarc is hollow, its tubular cavity being continuous with the cavities of the polypes, and containing a fluid in which a flickering movement may be observed, due to the presence of vibrating cilia. In the blastostyle both mouth and tentacles are absent, the zooid ending distally in a flattened disc; the hydrotheca of the polype is represented by the gonotheca (*gth*), which is a cylindrical capsule enclosing the whole structure, but ultimately becoming ruptured at its distal end to allow of the escape of the medusa-buds. These latter are, in the young condition, mere hollow offshoots of the blastostyle: when fully developed they have the appearance of saucers attached by the middle of the convex surface to the blastostyle, produced at the edge into sixteen very short tentacles, and having a blunt process, the *manubrium*, projecting from the centre of the concave surface. They are ultimately set free through the aperture in the gonotheca as little medusæ or jellyfish (B–D), which will be described hereafter.

The microscopical structure of Obelia reminds us, in its general features, of that of such a simple sponge as Ascetta, but with many characteristic differences. The body is composed of two layers of cells, the ectoderm and the endoderm, the latter ciliated; between them is a very delicate transparent membrane, the *mesoglæa* or *supporting lamella*, which, unlike the intermediate layer of sponges, contains no cells and is practically structureless.

The perisarc or transparent outer layer of the stem shows no cell-structure, but only a delicate lamination. It is, in fact, not a cellular membrane or epithelium, like the ectoderm and endoderm, but a *cuticle*, formed, layer by layer, as a secretion from the ectoderm cells (see p. 67). It is of chitinoid or horn-like consistency, and, like the lorica of many Protozoa, serves as a protective external skeleton.

Embedded in the ectoderm are numerous clear, ovoid bodies, the *stinging-capsules* or *nematocysts* (Fig. 42), serving as weapons of offence. Each consists (A) of a tough, ovoid capsule, full of a gelatinous material, and invaginated at one end in the form of a hollow process continued into a long, coiled, hollow thread. The whole apparatus is developed in an interstitial cell called a *cnidoblast* (*cnb*), which, as it approaches maturity, migrates towards the surface, and becomes embedded in one of the large ectoderm cells. At one point of its surface the cnidoblast is produced into a delicate protoplasmic process, the *cnidocil* or *trigger-hair* (*cnc*) : when this is touched — for instance by some small organism brought into contact with the waving tentacles — the cnidoblast undergoes a sudden contraction, and the pressure upon the stinging-capsule causes an instantaneous eversion of the thread (B), at the base of which are minute barbs. The threads or the gelatinous substance are poisonous and exert a numbing effect on the animals upon which the Obelia preys.

The structure of the Medusæ — formed as we have seen by the development of medusa-buds liberated from a ruptured gonangium — yet remains to be considered. The convex surface of the bell or umbrella (Fig. 41, B–D) by which the zooid was originally attached to the blastostyle, is distinguished as the *ex-umbrella*, the concave inner surface as the *sub-umbrella*. From the centre of the sub-umbrella proceeds the manubrium (*mnb*), at the free end of which is the four-sided mouth (*mth*). Very commonly as the medusa swims the umbrella becomes turned inside out, the sub-umbrella then forming the convex surface, and the manubrium springing from its apex (Fig. 41, *C*).

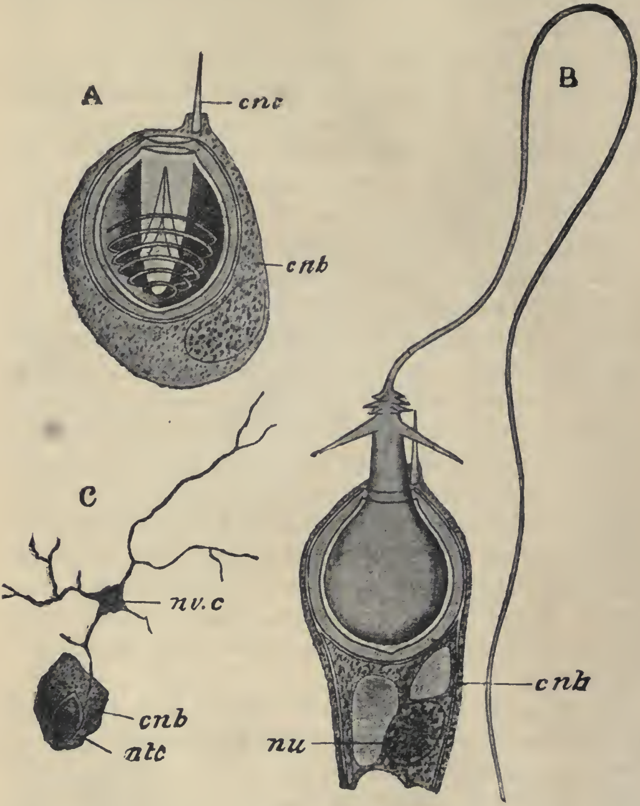

FIG. 42.—Nematocysts of hydra. A, undischarged; B, discharged; C, nerve-supply; *cnb*, cnidoblast; *cnc*, cnidocil; *nu*, nucleus; *ntc*, nematocyst; *nv.c*, nerve-cell. (From Parker's *Biology*, after Schneider.)

The mouth (Figs. 41, *C, D,* and 43, *mth*) leads into an enteric cavity which occupies the whole interior of the manubrium, and from its dilated base sends off four delicate tubes, the *radial canals* (*rad. c*), which pass at equal distances from each other through the substance of the umbrella to its margin, where they all open into a *circular canal* (*cir. c*), running parallel with and close to the margin. By means of this system of canals the food, taken in at the mouth and digested in the manubrium, is distributed to the entire medusa.

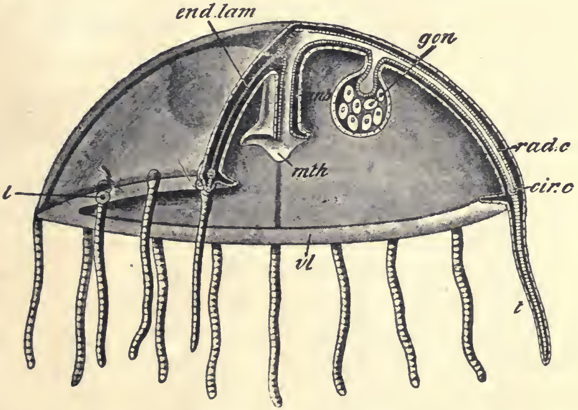

FIG. 43. — Dissection of a medusa with rather more than one-quarter of the umbrella and manubrium cut away (diagrammatic). The ectoderm is dotted, the endoderm striated, and the mesoglœa black. *cir. c,* circular canal; *end. lam,* endoderm lamella; *gon,* gonad; *l,* lithocyst; *mnb,* manubrium; *mth,* mouth; *rad. c,* radial canal; *vl,* velum.

The edge of the umbrella is produced into a very narrow fold or shelf, the *velum* (Fig. 43, *vl*), and gives off the tentacles (*t*), which are sixteen in number in the newly-born medusa (Fig. 41, *D*), but which are very numerous in the adult. At the bases of eight of the tentacles — two in each quadrant — are minute globular sacs (*l*), each containing a calcareous particle or *lithite*. These are the *marginal sense-organs* or *lithocysts:* they were formerly considered to be organs of hearing, and are hence frequently called *otocysts:* in all probability their function is to guide the medusa by enabling it to judge of the direction in which it is swimming. The marginal organs, in this case, may therefore be looked upon as organs of the sense of direction.

In the description of the fixed Obelia-colony no mention was made of cells set apart for reproduction, like the ova and sperms of a sponge. As a matter of fact, such sexual cells are only found, in their fully developed condition at least, in the medusæ. Hanging at equal distances from the sub-umbrella, in immediate relation with the radial canal, are four ovoid bodies (Fig. 43, *gon*), each containing a mass of cells which are developed either into ova or into sperms. As each medusa bears organs of one sex only (testes or ovaries as the case may be), the individual medusæ are *diœcious*.

When the gonads are ripe, the sperms of the male medusæ are shed into the water and carried by currents to the females, impregnating the ova, which thus become oosperms or unicellular embryos. The oosperm undergoes complete segmentation (Fig. 44, *A–F*), and is converted into an ovoidal ciliated body called a *planula* (*G*, *H*). The planula swims freely for a time (*H*), and then settles down on a piece of timber, seaweed, etc., fixes itself by one end (*K*), and becomes converted into a *hydrula* or simple polype (*L*, *M*), having a disc of attachment at its proximal end, and at its distal end a manubrium and circlet of tentacles. Soon the hydrula sends out lateral buds, and, by a frequent repetition of this process, becomes converted into the complex Obelia-colony with which we started.

This remarkable life-history furnishes the first example we have yet met with of *alternation of generations*, or *metagenesis*.

The Obelia-colony is sexless, having no gonads, and developing only by the asexual process of budding; but certain of its buds — the medusæ — develop gonads, and from their impregnated eggs new Obelia-colonies arise. We thus have an alternation of an *asexual generation* — the Obelia-colony — with a *sexual generation*, the medusa.

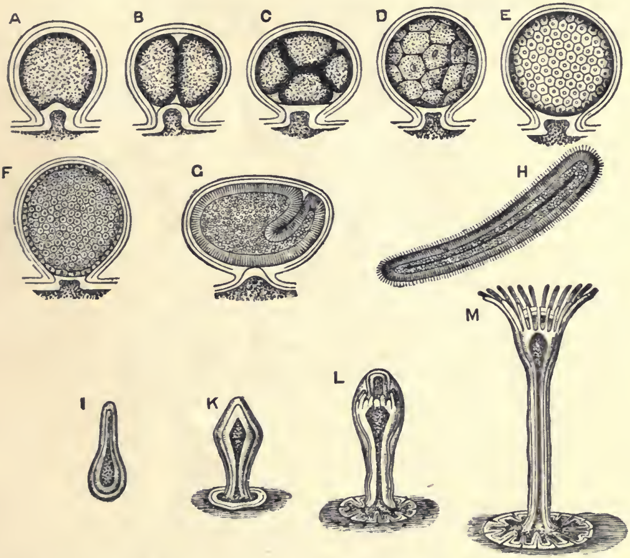

FIG. 44. — Stages in the development of two zoophytes (A–H, **Laomedea**, I–M, **Eudendrium**) allied to Obelia; A–F, stages in segmentation; G, the planula enclosed in the maternal tissues; H, the free-swimming planula; I–M, fixation of the planula and development of the hydrula. (From Parker's *Biology*, after Allman.)

The majority of the **Hydrozoa** resemble Obelia in forming fixed colonies; but there are a few exceptional cases in which the animal remains simple. One of these is *Hydra*, the Fresh-water Polype. In Hydra the entire organism (Fig. 45) consists of a simple cylindrical body with a conical hypos-

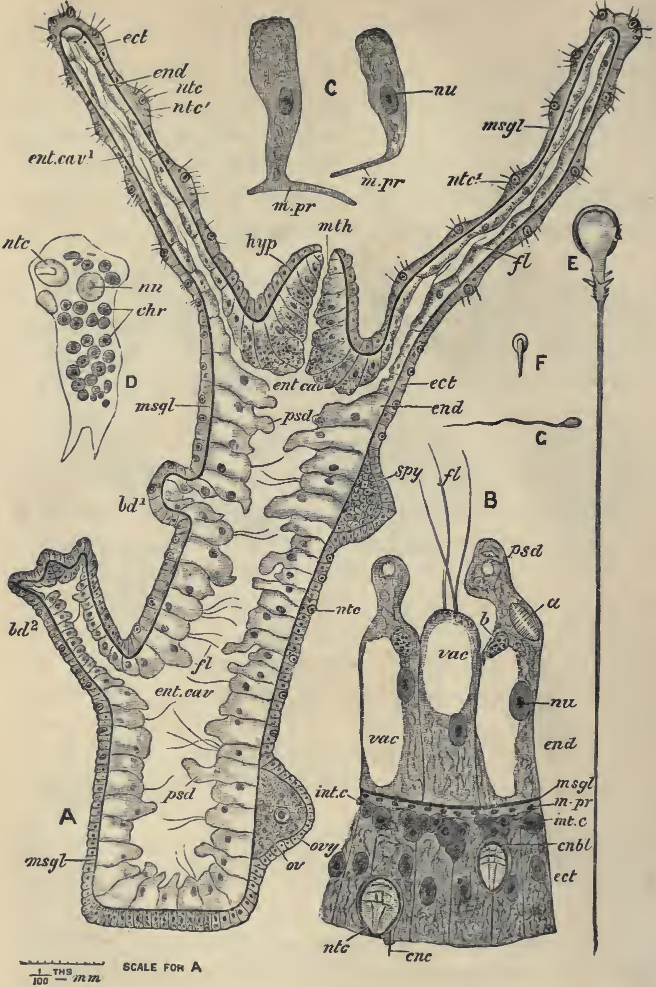
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Fig 45. — **Hydra.** A vertical section of entire animal; B, portion of transverse section, highly magnified; C, two large ectoderm cells; D, endoderm cell of *H. viridis*; E, large nematocyst; F, small nematocyst; G, sperm; *a*, ingested diatom; *bd.*^{1}, *bd.*^{2}, buds; *chr*, chromatophores; *cnbl*, cnidoblast; *cnc*, cnidocil; *ect*, ectoderm; *end*, endoderm; *ent. cav*, enteric cavity; *ent. cav*^{1}, its prolongation into the tentacles; *fl*, flagellum; *hyp*, hypostome or manubrium; *int. c*, interstitial cells; *m. pr*, muscle processes; *mth*, mouth; *msgl*, mesoglœa; *nct*, large, and *ntc*^{1}, small nematocysts; *nu*, nucleus; *ov*, ovum; *ovy*, ovary; *psd*, pseudopods; *spy*, spermary; *vac*, vacuole.

tome and a circlet of from six to eight tentacles surrounding the mouth. It is ordinarily attached, by virtue of a sticky secretion from the proximal end, to weeds, etc., but is capable of detaching itself and moving from place to place after the manner of a looping caterpillar. The tentacles are hollow, and communicate freely with the enteron. There is no perisarc. Buds are produced which develop into Hydræ; but these are always detached sooner or later, so that a permanent colony is never formed. There are no special reproductive zooids, but simple ovaries (*ovy*) and testes (*spy*) are developed, the former nearer the proximal, the latter nearer the distal end of the body.

In nearly all the remaining Hydrozoa that do not form colonies the form assumed is not that of the *polype*, but that of the *medusa* (Fig. 46), a polype stage never being developed, and the animal resembling in all essential respects the medusæ of Obelia; the chief difference of importance being the presence of sense-organs in the form of hollow, club-shaped appendages, the *tentaculocysts*, containing calcareous bodies of *lithites*. These simple free-swimming medusiform Hydrozoa (*Trachylinæ*) develop ova and sperms which give rise to free-swimming ciliated larvæ; but the latter, instead of becoming fixed and developing into plant-like colonies, remain free, and develop directly into medusæ like those from which they originated. The fixed zoophyte stage is thus absent in the life-history, and an alternation of generations is not recognisable.

In the colonial Hydrozoa, which constitute the great majority of the class, the colony in most instances resembles that of Obelia in being a fixed structure consisting of a slender branching stem, covered over by perisarc, and bearing zooids and blastostyles. In many the perisarc is produced to form hydrothecæ and gonothecæ for the protection of the polypes and blastostyles respectively; but in others (Fig. 47) these protecting structures are absent. The polypes resemble those of Obelia in all essential respects, but differ in the number and arrangement of the tentacles and other minor points. In many medusæ are developed from blastostyles as in Obelia, and when fully formed become free. The shape of the medusa

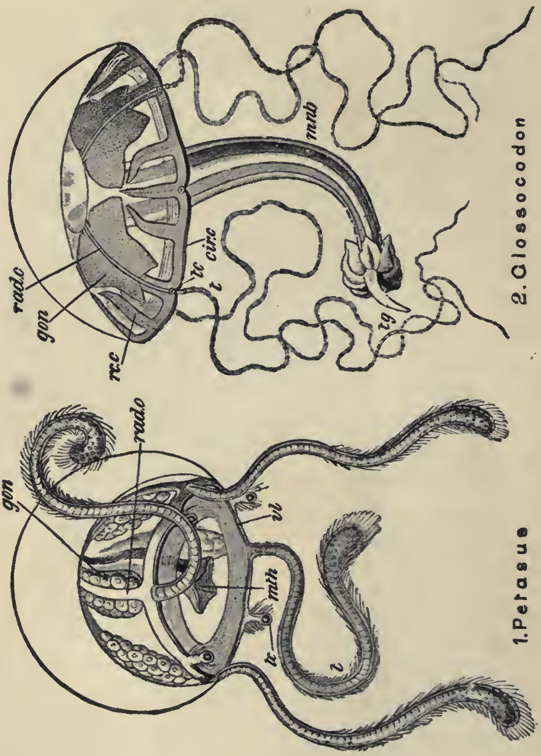
1. Petasus
gon
rad.c
vl
mth
tc
t
2. Glossocodon
rad.c
gon
rc.c
tc
t
cir.c
mnb
tg

FIG. 46.—Two Trachylinæ. *cir. c*, circular canal; *gon*, gonad; *mnb*, manubrium; *mth*, mouth; *rad. c*, radial canal; *rc. c*, recurrent canal; *t*, tentacle; *tc*, tentaculocyst; *tg*, tongue; *vl*, velum. (After Haeckel.)

differs in different forms, more particularly as regards the umbrella. There is always a manubrium, with gastric

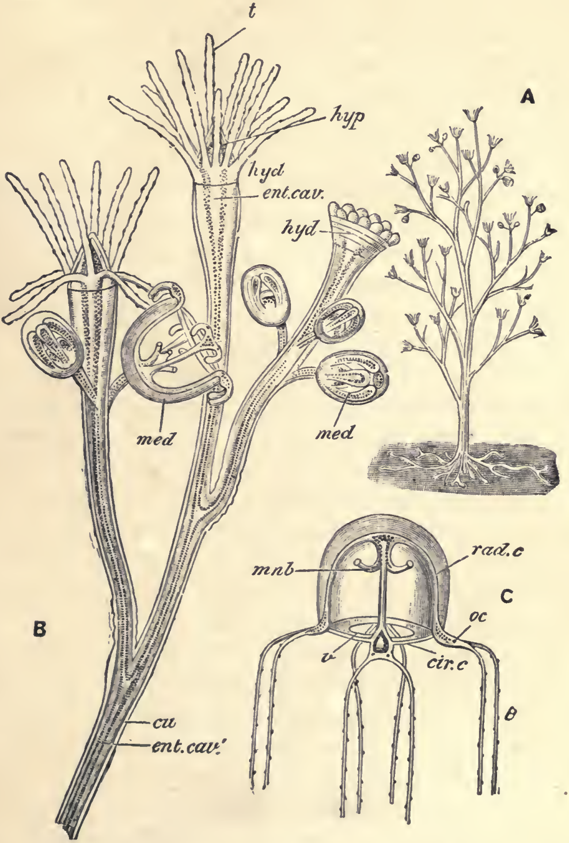
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FIG. 47. — **Bougainvillea ramosa.** A, entire colony, natural size; B, portion of the same magnified; C, immature medusa; *cir. c*, circular canal; *cu*, cuticle or perisarc; *ent. cav*, enteric cavity; *hyd*, polype or hydranth; *hyp*, hypostome or manubrium; *med*, medusa; *mnb*, manubrium; *rad. c*, radial canal; *t*, tentacle; *v*, velum. (From Parker's *Biology*, after Allman.) This is closely allied to the New England *B. superciliaris.*

cavity, and a marginal and four radial canals, and a velum is universally present. But lithocysts are not present in all, their place being taken by specks of red or black pigment — the *ocelli* or rudimentary eyes — at the bases of the tentacles. The number and arrangement of the tentacles is subject to considerable variation. The gonads are sometimes, as in Obelia, developed in the radial canals, sometimes in the manubrium. In size the medusæ range from about 1 up to 400 millimetres (16 inches) in diameter.

In many of the zoophytes, however, the medusæ never become detached from the colony, developing the ova and sperms without becoming free. In such cases the characteristic medusa structure is more or less imperfectly developed, and in many forms is not at all recognisable, the buds corresponding to those which in Obelia give rise to medusæ merely developing into rounded outgrowths termed *sporosacs*, in the interior of which the ova and sperms are formed.

The reproductive buds are not in all cases formed, as in Obelia, on distinct, peculiarly modified, mouthless zooids. In many instances, whether they are destined to give rise to medusæ or sporosacs, the buds spring directly from the cœnosarc, or from the ordinary zooids.

A small group of Hydrozoa — the **Hydrocorallina** — including the Millepores (*Millepora*) and *Stylaster*, form colonies, the supporting material of which, instead of being chitinoid, is of calcareous and stony character, like the substance of a coral.

The colonies of Hydrozoa are not in all instances attached, like those of Obelia and the other hydroid zoophytes. In one large order, the **Siphonophora**, the colonies of zooids float or swim freely in the sea. In some Siphonophora there are no organs for active locomotion, and the colony drifts about, completely at the mercy of wind and tide, buoyed up by a bladder-like float or *pneumatophore* containing air. Such a passively floating form is the Portuguese Man-of-war (*Physalia*) (Figs. 48, 49) which has an elongated float, pointed at the ends, and produced above, along its upper edge, into a crest or sail (*cr.*). At one end is a minute aperture communicating with the exterior. From the under side of the float hang polypes (*p*), feelers, groups of medusa-buds looking like bunches of grapes of a deep blue colour, and long retractile tentacles, sometimes several feet in length, and containing batteries of stinging-capsules powerful enough to sting the hand as severely as a nettle. The male reproductive buds remain attached and take the form of sporosacs, while the female buds apparently become detached as free medusæ. *Physalia arethusa* is common in the West Indies, and, borne northward by the Gulf Stream, is occasionally met with on the coast of southern New England, and off Nova Scotia.

In such a Siphonophoran as **Halistemma** (Fig. 50), on the other hand, there is a long, slender, flexible stem or cœnosarc, at the upper end of which is a comparatively small float. Next to this come a number of closely set, transparent structures (*nct*), having the general characters of unsymmetrical medusæ without manubria, each being a deep, bell-like body, with a velum and radiating canals. During life these *swimming-bells* or *nectocalyces* contract rhythmically, — *i.e.*, at regular intervals, — thus serving to propel the entire organism through the water. Below the last nectocalyx the character of the structures borne by the stem changes completely: they are of several kinds, and are arranged in groups which follow one another at regular intervals.

Some of these are unmistakable polypes (*p*) differing,

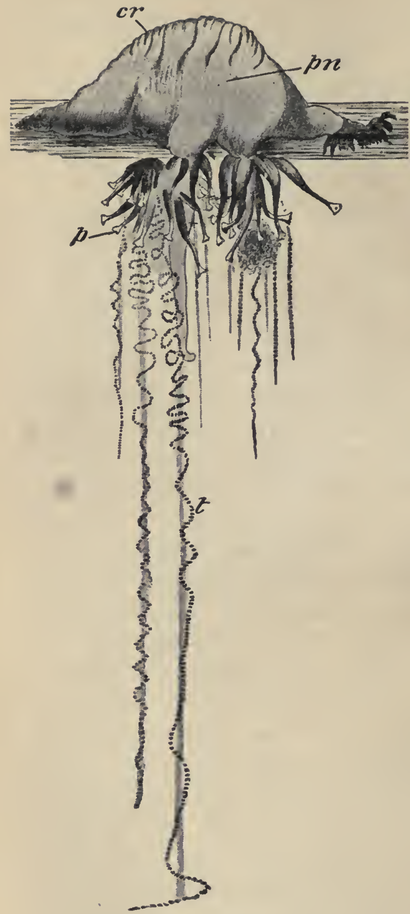


FIG. 48. — **Physalia.** The living animal floating on the surface of the sea. *cr*, crest ; *p*, polype ; *pn*, pneumatophore, float, or air-sac. (After Huxley.)

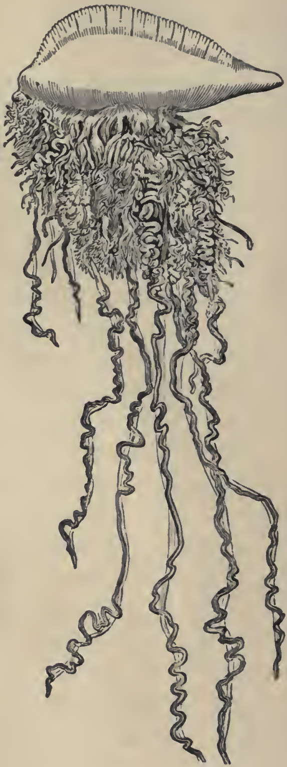
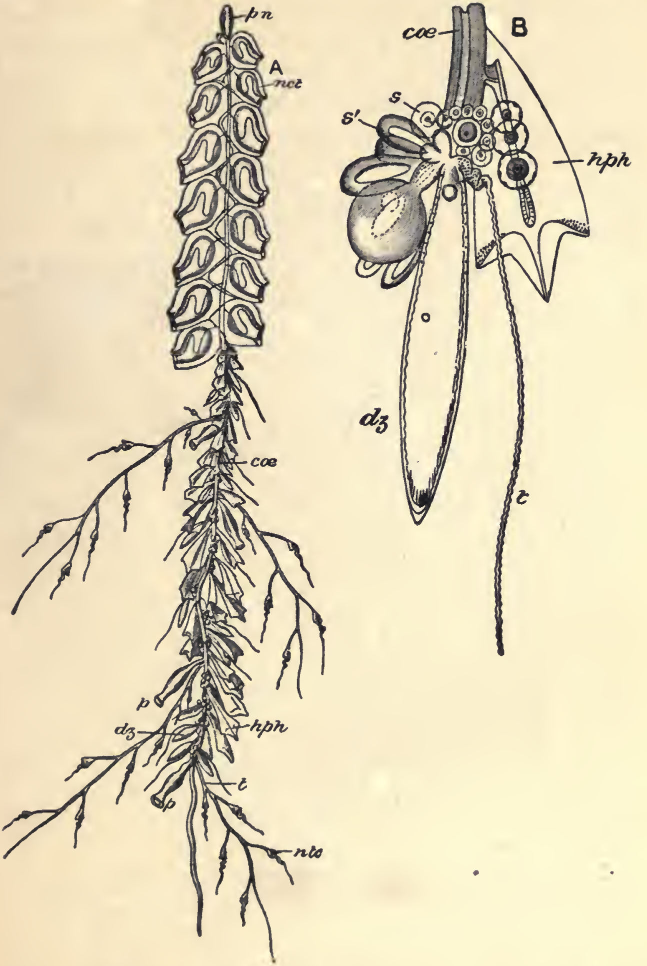


FIG. 49. — *Physalia arethusa*, natural size. (After Agassiz.)


pn
A
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B
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FIG. 50.—**Halistemma tergestinum.** A, the entire colony; B, a single group of zooids; *cœ*, cœnosarc; *dz*, dactylozooid; *hph*, hydrophyllium or bract; *nct*, nectocalyx or swimming-bell; *ntc*. battery of nematocysts; *p*. polype; *pn*, pneumatophore or float; *s*, *s'*, sporocysts; *t*, tentacle. (After Claus.)

however, from those we have hitherto met with, in having no circlet of tentacles round the mouth, but a single, long, branched tentacle (*t*) arising from its proximal end, and bearing numerous groups or "batteries" of stinging-capsules (*ntc*). Others are *dactylozooids* or feelers (*dz*) — mouthless polypes, each with an unbranched tentacle springing from its base. Near the bases of the polypes and dactylozooids spring groups of sporosacs (B, *s*, *s'*), some male, others female; and finally delicate, leaf-like transparent bodies — the *bracts* or *hydrophyllia* (*hph*) — partly cover the sporosacs. Halistemma occurs in the Atlantic and Mediterranean. A closely related form (*Agalmopsis cara*) occurs off the coast of New England.

2. THE SCYPHOZOA

Aurelia, which may be taken as an example of the **Scyphozoa**, is the most common of our larger jellyfishes, and is often found cast up on the sea-shore, where it is readily recognisable by its gelatinous saucer-shaped umbrella, from eight to twelve, and sometimes fifteen inches in diameter, having near the centre four red or purple horseshoe-shaped bodies — the gonads — lying embedded in the jelly.

The general arrangement of the parts of the body (Fig. 51) is very similar to what we are already familiar with in the hydrozoan jellyfishes (Figs. 41 and 43). Most conspicuous is the concavo-convex *umbrella*, the convex surface of which, or *ex-umbrella*, is uppermost in the ordinary swimming position. The outline is approximately circular, but is broken by eight notches, in each of which lies a pair of delicate processes, the *marginal lappets* (*mg. lp*) with a peculiar *sense-organ;* between the pairs of lappets the edge of the umbrella is fringed by numerous close-set *marginal tentacles* (*t*).

In the centre of the lower or sub-umbrella surface is a four-sided aperture, the *mouth* (*mth*), borne at the end of an extremely short and inconspicuous *manubrium:* surrounding it are four long delicate processes, the *oral arms*

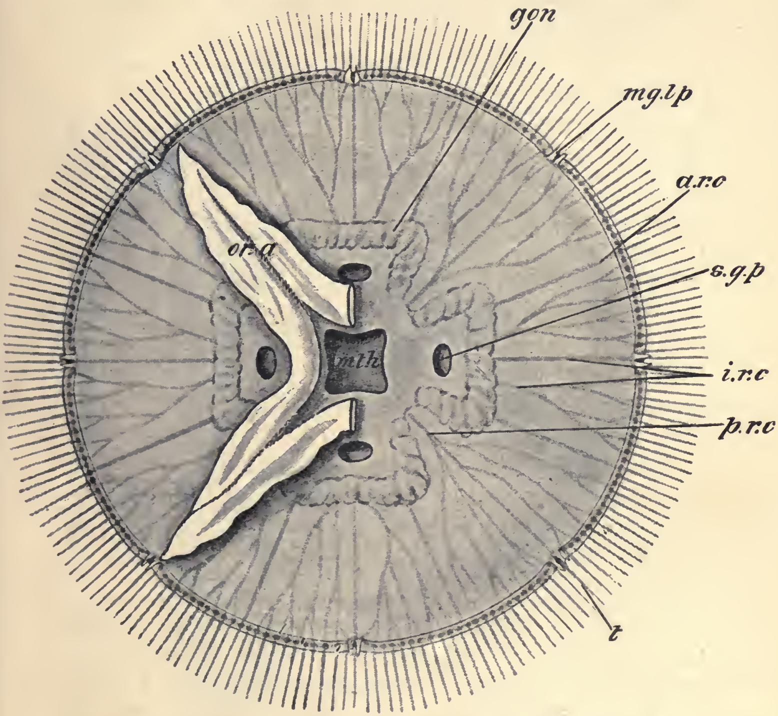

Fig. 51.—**Aurelia aurita**. Ventral view—two of the oral arms are removed; *a.r.c*, radial canal; *gon*, gonads; *i.r.c*, radial canal; *mg. lp*, marginal lappet; *mth*, mouth; *or. a*, oral arm; *p.r.c*, radial canal; *s.g.p*, sub-genital pit; *t*, tentacles.

(*or. a*), situated one at each angle of the mouth and uniting round it.

At a short distance from each of the straight sides of the mouth is a nearly circular aperture leading into a shallow pouch, the *sub-genital pit* (*s. g. p*), which lies immediately beneath one of the conspicuously coloured gonads (*gon*).

The mouth leads by a short tube or *gullet*, contained in the manubrium, into a spacious *stomach*, which is produced into four wide inter-radial *gastric pouches*, which extend about halfway from the centre to the circumference. In the outer or peripheral wall of each gastric pouch are three small apertures, leading into as many *radial canals* (*a.r.c*, *i.r.c*, *p.r.c*), which pass to the edge of the umbrella and then unite in a very narrow *circular canal*.

Each gonad (*gon.*) is a horseshoe-shaped frill-like structure situated on the floor of the gastric pouch. When mature, its products—ova or sperms—are discharged into the stomach, and pass out by the mouth. The sexes are lodged in distinct individuals.

Lying parallel with the inner or concave border of each gonad is a row of delicate filaments supplied with stinging-capsules. These are the *gastric filaments*: their function is to kill or paralyse the prey taken alive into the stomach (compare Fig. 53, *g. f*).

The development and life-history of Aurelia present several striking and characteristic features. The impregnated egg-cell or oosperm becomes converted into a closed two-layered sac or *planula* (Fig. 52, A), similar to that of a Hydrozoon. The planula swims about by means of the cilia with which its ectodermal cells are provided, and, after a brief free existence, settles down, loses its cilia, and becomes attached by one pole. At the opposite pole a mouth is formed. On two opposite sides of the mouth hollow

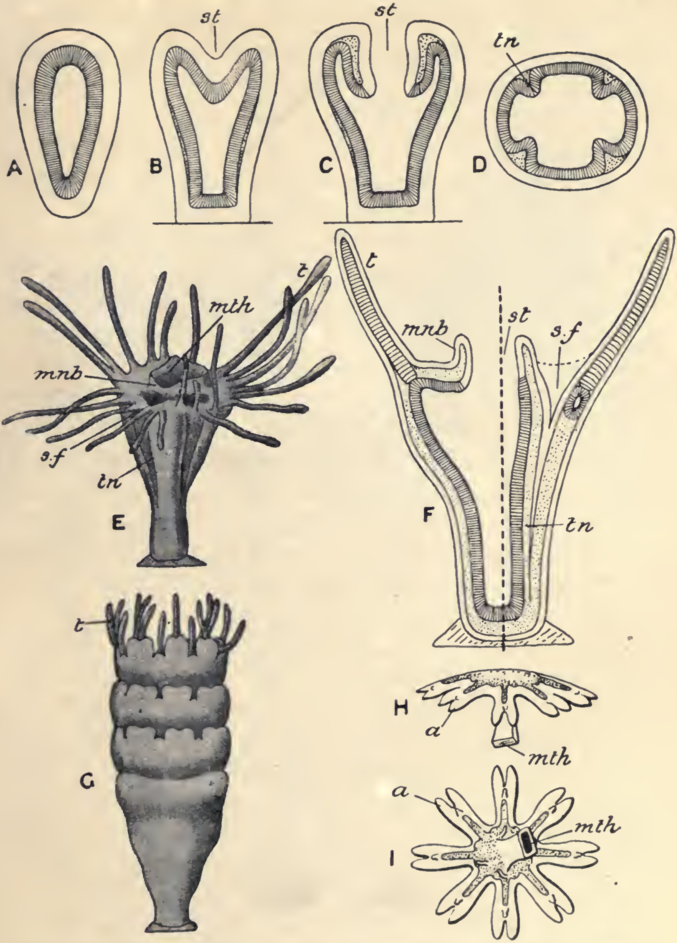

FIG. 52. — **Aurelia aurita**, development A, planula: B, C, formation of the gullet or stomodæum; D, transverse section of young scyphula; E, scyphula; F, longitudinal section of same; G, division of scyphula into ephyrulæ; H, ephyrula from the side; I, the same from beneath. In A D and F the ectoderm is unshaded, the endoderm striated, and the mesoglœa dotted. *a*, lobes of umbrella; *mnb*, manubrium; *mth*, mouth; *s f*, septal funnel; *st*, stomodæum; *t*, tentacle: *tn*, tænioles, or gastric ridges. (From Korschelt and Heider's *Embryology*)

processes grow out, forming the first two tentacles; soon two others appear at right angles to these. Subsequently other tentacles appear. At the same time the attached or proximal end is narrowed into a stalk-like organ of attachment (E).

The outcome of all these changes is the metamorphosis of the planula into a polype (F), not unlike a Hydra. The Scyphozoon-polype is called a *Scyphula*. The Scyphula sometimes multiplies by budding. After a time it undergoes a process of transverse fission (G), becoming divided by a series of constrictions which deepen until the polype assumes the appearance of a pile of saucers, each with its edge produced into eight bifid lobes. Soon the process of constriction is completed, the saucer-like bodies separate from one another, and each, — except the first topmost one, which falls off and dies, — turning upside down, begins to swim about as a small jellyfish called an *Ephyrula* (H, I), which grows rapidly and eventually develops into the adult Aurelia.

The rest of the **Scyphozoa** resemble Aurelia in the general features of their structure, but there is a good deal of variation in certain points (Fig. 52). Thus the umbrella, instead of being a saucer-shaped disc, as in Aurelia, is often conical or cup-shaped or cubical. In some, tentaculocysts are not developed, and in others the oral arms are absent. *Lucernaria* differs somewhat widely from the rest in being attached by means of a short stalk developed from the centre of the ex-umbrella. In the *Rhizostomeæ* the mouth is obliterated by the union of the bases of the oral arms, the food being taken in through a large number of minute orifices scattered over the surface of the arms, and leading into a system of fine canals, which join together to form larger canals, eventually opening into the gastric cavity. Many of the Scyphozoa pass through an alternation of generations similar to that which has been described in the case of Aurelia, with a fixed scyphistoma stage; but in others the ciliated larvæ developed from the ova give rise directly to jellyfishes like the parent, without the intercalation of any fixed stage.

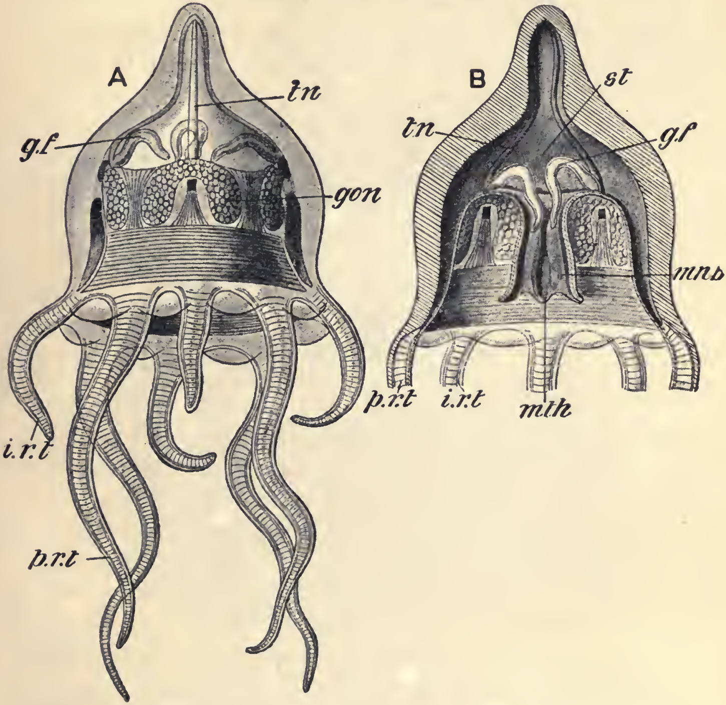

FIG. 53.—**Tessera princeps.** A, external view; B, vertical section; *g. f*, gastric filament; *gon*, gonad; *i.r.t*, tentacle; *mnb*, manubrium; *mth*, mouth; *p.r.t*, tentacle: *st*, stomach; *tn*, tæniole or gastric ridge. Antarctic Ocean. (After Haeckel.)

The Scyphozoa are all marine, and the majority are *pelagic*, *i.e.*, swim freely in the surface waters of the ocean.

A few inhabit the deep sea, and have been dredged from as great a depth as 2000 fathoms. Nearly all are free-swimming in the adult state; some, however, live on coral-reefs or mud-banks, and are found resting, in an inverted position, on the ex-umbrella; and a few, such as Lucernaria, are able to attach themselves at will by a peduncle. Many are semi-transparent and glassy, but often with brilliantly coloured gonads, tentacles, or radial canals. In many cases the umbrella, oral arms, etc., are highly coloured, and some species are phosphorescent. They are all carnivorous, and, although mostly living on smaller organisms, are able, in the case of the larger species, to capture and digest crustaceans and fishes of considerable size.

3. THE ACTINOZOA

The simplest and most familiar of the Actinozoa are the **Sea-anemones**, which are to be found attached to rocks, seaweeds, shells, etc., on the sea-shore. When expanded a sea-anemone has the form of a cylindrical column attached to a rock or other support by a broad *base*. The distal or free surface of the column, termed the *disc* or *peristome*, bears in the middle an elongated, slit-like aperture—the *mouth*. Springing from the disc and encircling the mouth are numerous cylindrical *tentacles*, disposed in circlets, their total number being some multiple of five.

Obviously the sea-anemone is a polype, formed on the same general lines as a polype of the Hydrozoa. But certain important differences from the Hydrozoan polype become manifest when we examine the internal structure (Fig. 54). The mouth does not lead at once into a spacious undivided enteric cavity, but into a short tube (*gul*), having the form of a flattened cylinder, which hangs downward into the interior of the body, and terminates in a free edge. This tube is called the *gullet* or stomodæum. Its inner surface is marked with two longitudinal grooves (*sgph*), known as the gullet-grooves or *siphonoglyphes*. The gullet does not simply hang freely in the interior cavity, but is connected with the body-wall by a number of radiating partitions, the complete or *primary mesenteries* (*mes. 1*); between these are incomplete *secondary mesenteries* (*mes. 2*), which extend only part of the way from the body-wall to the gullet, and *tertiary mesenteries* (*mes. 3*), which are hardly more than ridges on the inner surface of the body-

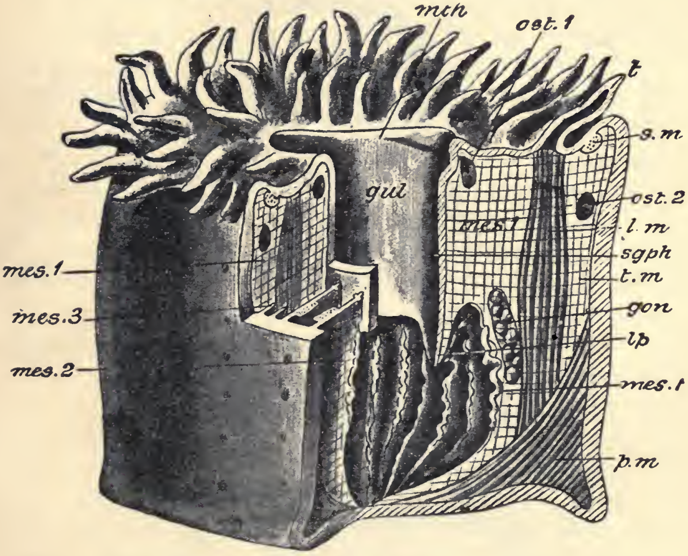

FIG. 54.—**Tealia crassicornis.** Dissected specimen; *gon*, gonads; *gul*, gullet; *l. m*, longitudinal muscle; *lp*, lappet; *mes. 1*, primary, *mes. 2*, secondary, *mes. 3*, tertiary mesenteries; *mes. F*, mesenteric filaments; *mth*, mouth; *ost. 1*, *ost. 2*, ostia or aperture in mesenteries; *p. m*, parietal muscle; *sgph*, siphonoglyphe; *s. m*, sphincter muscle; *t. m*, transverse muscle.

wall. Thus the entire enteric cavity of a sea-anemone is divisible into three regions: (1) the *gullet* or stomodæum, communicating with the exterior by the mouth, and opening below into (2) a single main digestive cavity, the stomach, which gives off (3) a number of radially arranged cavities, the inter-mesenteric chambers. The free edges of the mesenteries below the gullet are produced into curious

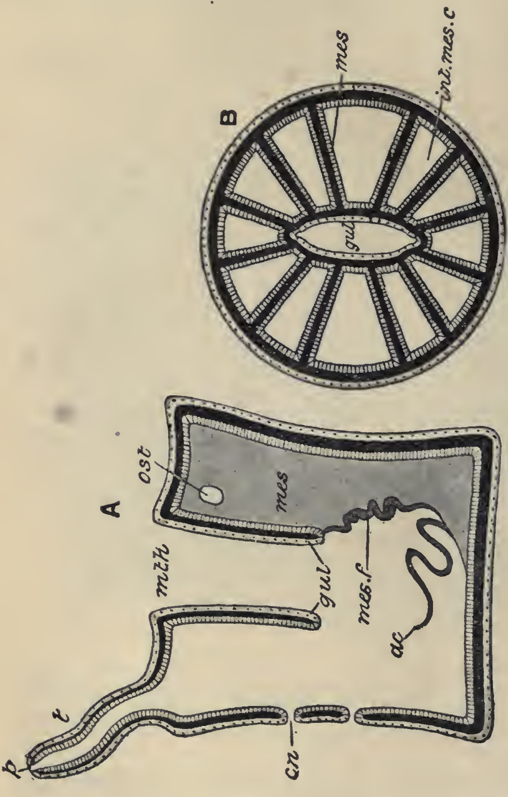

FIG. 55.—Diagrammatic vertical (A) and transverse (B) sections of a sea-anemone. The ectoderm is dotted, the endoderm striated, the mesoglœa black. *ac*, acontium; *cn*, cinclis or aperture in body-wall; *gul*, gullet; *int. mes. c*, intermesenteric chamber; *mes*, mesentery; *mes. f*, mesenteric filament; *mth*, mouth; *ost*, ostium; *p*, pore; *t*, tentacle.

twisted cords, the *mesenteric filaments* (*mes. F*), answering to the gastric filaments of Scyphozoa. Stinging-capsules occur in the ectoderm, and are also very abundant in the mesenteric filaments. They resemble in general character the nematocysts of Hydrozoa, but are of a more elongated form, and the thread is usually provided at the base with very numerous slender barbs.

In virtue of possessing both stinging-capsules and gland-cells, the mesenteric filaments perform a double function. The animal is very voracious, and is able to capture and swallow small fishes, molluscs, sea-urchins, etc. The prey is partly paralysed before ingestion by the nematocysts of the tentacles, but the process is completed, after swallowing, by those of the mesenteric filaments. Then, as the captured animal lies in the stomach, the edges of the filaments come into close contact with one another and practically surround it, pouring out at the same time a digestive juice secreted by their gland-cells.

Sea-anemones are diœcious, the sexes being lodged in distinct individuals. The gonads—ovaries or testes—are developed in the substance of the mesenteries (Fig. 54, *gon*), a short distance from the edge, and, when mature, often form very noticeable structures. The development of sea-anemones resembles, in its main features, that of Scyphozoa, but there is no alternation of generations.

Our common sea-anemone, *Metridium marginatum* (Fig. 56), lives under stones near low-water mark.

Two main divisions or sub-classes of the **Actinozoa** are recognised,—the **Zoantharia** and the **Alcyonaria**, the former including the sea-anemones, the Madrepores, and other stony corals, and the horny black corals; the latter the "dead men's fingers," red coral, organ-pipe coral, "sea-fans," and "sea-pens." The principal distinguishing features of the two sub-classes are, that in the Zoantharia the tentacles and mesenteries are usually very numerous, and are arranged, as a rule, in multiples of five or six, and that the tentacles are simple in form; while in the Alcyonaria (Fig. 58) the tentacles and mesenteries are always eight in number, and the tentacles are pinnate, *i.e.*, each of them consists of a main stem with two rows of lateral branchlets.

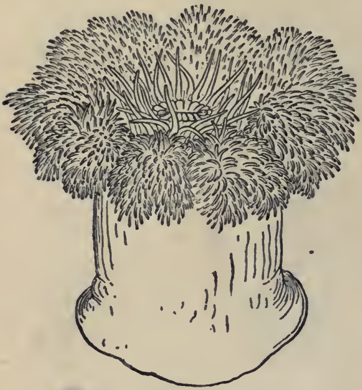

FIG. 56. — The common Sea-anemone. (After Emerton.)

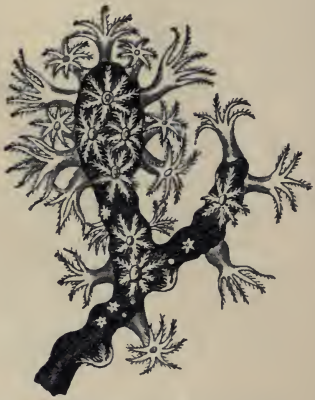

FIG. 57. — **Corallium rubrum**, portion of colony. Enlarged twice. (After Lacaze-Duthiers.)

Only the sea-anemones (with a few exceptions) and a few Madrepore corals remain simple, the rest all giving rise to more or less extensive colonies, of a variety of different forms, by continuous budding. The structure of the zooids is similar to that of the sea-anemone in all essential respects. In many of the Alcyonaria two forms of zooids are to be distinguished in each colony (*dimorphism* of the zooids), ordinary zooids, and *siphonozooids*, which are smaller, and are devoid of tentacles and of gonads.

None of the sea-anemones have a true skeleton; in some, however, there is a thick cuticle, and several kinds enclose themselves in a more or less complete tube, which may be largely formed of discharged nematocysts. In some Alcyonaria, such as the "dead men's fingers" (*Alcyonium*, Fig. 58), the skeleton consists of minute, scattered, irregular deposits of carbonate of lime called *spicules*. *Alcyonium carneum* occurs below tide-mark off the New England coast. In *Tubipora* (the "organ-pipe coral") (Fig. 59) there is a con-

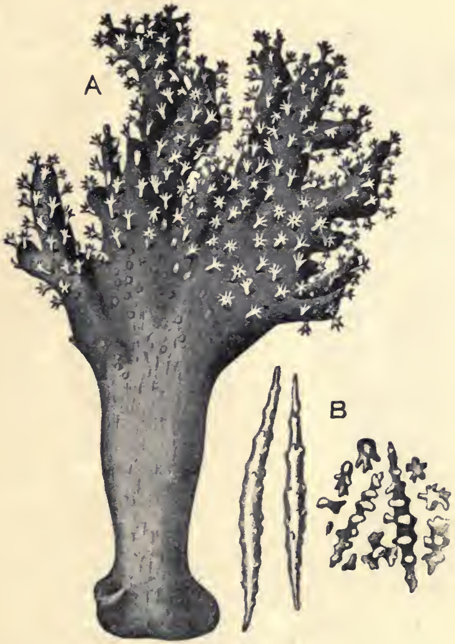

FIG. 58. — **Alcyonium palmatum.** A, entire colony natural size; B, spicules. Mediterranean Sea. (After Cuvier.)

tinuous calcareous tube for each polype. In the red coral of commerce (Fig. 57), which inhabits the Mediterranean Sea, there is an extremely hard calcareous branched rod which extends as an axis through the cœnosarc. In the black corals (*Antipathes* and allies) there is a horn-like axis ; and in Gorgonia there is a similar skeleton, sometimes partly calcareous, with the addition of numerous spicules. In the sea-pens (Fig. 60) the colony is supported by an unbranched horny axis. *Pennatula aculeata* lives in deep water in the North Atlantic.

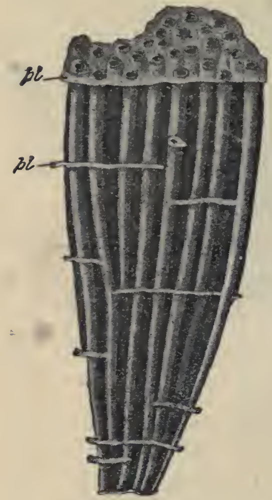

FIG. 59. — **Tubipora musica.** Skeleton of entire colony. Natural size. *pl*, platform. Indian Ocean. (After Cuvier.)

In the *Madrepore corals* we have a skeleton of an entirely different type, consisting, in fact, of a more or less cup-like calcareous structure secreted from the ectoderm of the base and column of the polype. When formed by a solitary polype such a "cup-coral" is known as a *corallite ;* in the majority of species a large number — sometimes many thousands — of corallites combine to form a *corallum*, the skeleton of an entire coral-colony.

The structure of a corallite is conveniently illustrated by that of the solitary genus *Flabellum* (Fig. 61, A, B). It has the form of a short conical cup, much compressed, so as to be oval in section. Its wall or *theca* is formed of dense stony calcium carbonate, the proximal end produced into a short stalk or *peduncle*. From the inner surface of the theca a number of radiating partitions, the *septa*, proceed inwards or towards the axis of the cup, some of them meeting in the middle to form an irregular central mass or *columella*, which in some kinds of corals forms an independent, pillar-like structure arising from the middle of the base.

In the living condition the polype fills the whole interior of the corallite, and projects beyond its edge to a greater or less degree according to its state of expansion. The septa alternate with the mesenteries, each being invested by an in-turned portion of the body-wall; so that, though having at first sight the appearance of being internal structures, they are really external, lying altogether outside the enteric cavity, and are in contact throughout with the ectoderm.

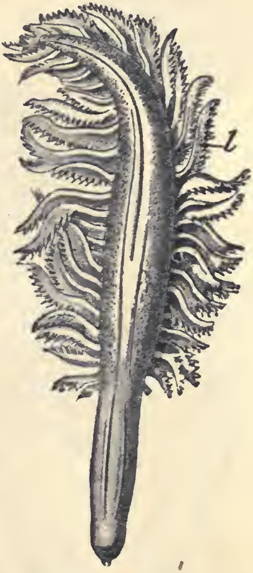

Fig. 60.—Pennatula sulcata. Entire colony. Natural size. *l*, lateral branch. (After Koelliker.)

The almost infinite variety in form of the compound corals is due, in the main, to the various methods of budding. According to the mode of budding, massive corals are produced in which the corallites are in close contact with one another, as in *Astræa* (Fig. 62); or tree-like forms, such as *Dendrophyllia* (Fig. 63, A), in which a common calcareous stem, the *cœnenchyma*, is formed by calcification of the cœnosarc,[1] and gives origin to the individual corallites.

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[1] See p. 94.

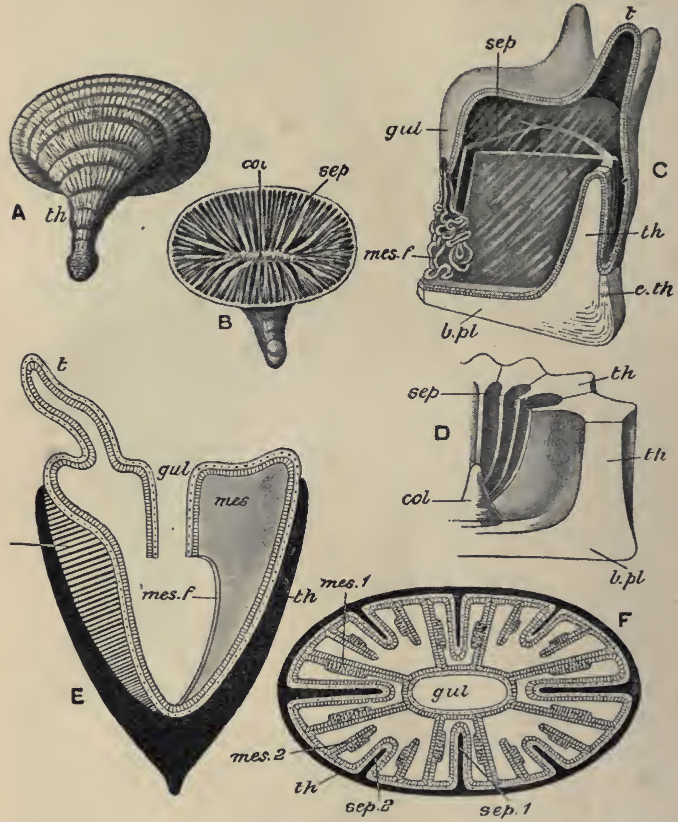
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FIG. 61. — A, B, two views of **Flabellum curvatum**. Natural size. C, semi-diagrammatic view of a simple coral; D, portion of a corallite; E, F, diagram of a simple coral in longitudinal and transverse section; ectoderm dotted, endoderm striated, skeleton black. *b. pl*, basal plate; *col*, columella; *e. th*, epitheca; *gul*, gullet; *mes.*, *mes. 1*, *mes. 2*, mesenteries; *mes. f*, mesenteric filaments; *sep*, septa; *t*, tentacle; *th*, theca. (A and B after Moseley; C and D after Gilbert Bourne.)

It is by this last-named method, the cœnosarc attaining great dimensions, and the individual corallites being small and very numerous, that the most complex of all corals, the Madrepores (Fig. 63, B), are produced.

The Actinozoa are remarkable for the variety and brilliancy of their colour during life. Every one must have noticed the vivid and varied tints of sea-anemones; but in life the corals also exhibit a marvellously varied and gorgeous colouring; and the same holds good of many of the Alcyonaria.

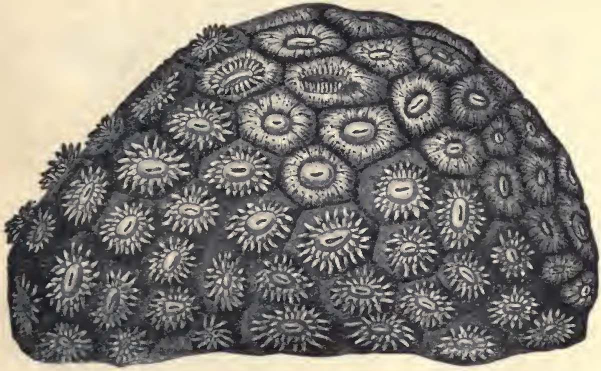

FIG. 62. — **Astræa pallida,** the living colony. Natural size. Fiji Islands. (After Dana.)

Many Actinozoa, like many sponges (p. 89), furnish examples of commensalism, a term used for a mutually beneficial association of two organisms of a less intimate nature than occurs in symbiosis. An interesting example is furnished by the sea-anemone *Adamsia palliata.* This species is always found on a univalve shell — such as that of a whelk — inhabited by a hermit-crab. The sea-anemone is carried from place to place by the hermit-crab, and in this way secures a more varied and abundant food-supply than would fall to its lot if it remained in one place. On the other hand, the hermit-crab is protected from the attack of predaceous fishes by retreating into its shell and leaving exposed the sea-anemone, which, owing to its toughness, and to the pain caused by its poisonous stinging-capsules, is usually avoided as an article of food.

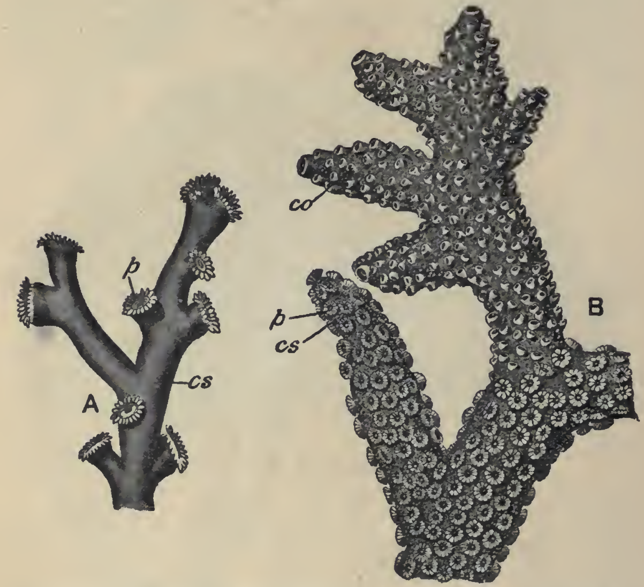

FIG. 63. — A, **Dendrophyllia nigrescens**; B, **Madrepora aspera**. Natural size. *co*, corallites; *cs*, cœnosarc; *p*, polypes. Pacific Ocean. (After Dana.)

A similar case is that of *Cancrisocia*, of the China seas, which lives on the back of a crab (*Dorippe facchino*, Fig. 64). The crab carries, for its protection when young, a small shell over its back, which it holds in this position by means of its two reversed pairs of hind legs. The sea-anemone appears to have fixed itself when young to the shell, and afterwards, by its growth, spread over the back of the crab, taking the place of the shell.

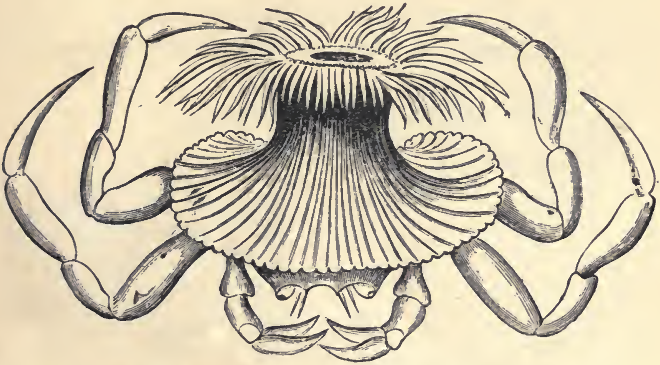

Fig. 64. — Cancrisocia living as a commensal on the back of a crab. (After Verrill.)

4. THE CTENOPHORA

The **Ctenophora** or comb-jellies are a group of free-swimming, gelatinous, transparent animals which occur, sometimes in enormous numbers, in the surface waters of the sea. The animal (Fig. 65) has the appearance of a mass of clear jelly, usually of a globular shape; and no pulsating movements, such as those by means of which a Medusa propels itself, are to be observed. Running over the surface, nearly from pole to pole of the globular body, there will be observed a series of eight bands of flashing points of light. These are found, when examined more closely, to consist of rows of long cilia, which run at right angles to the long axis of the band. The cilia of each row are cemented together at their bases, free from one another distally, so that each row is comb-shaped, the basal cemented parts of the cilia forming the back of the comb, the free portions the teeth. It is by the paddling action of the numerous swimming combs of these eight bands that the ctenophore is propelled through the water.

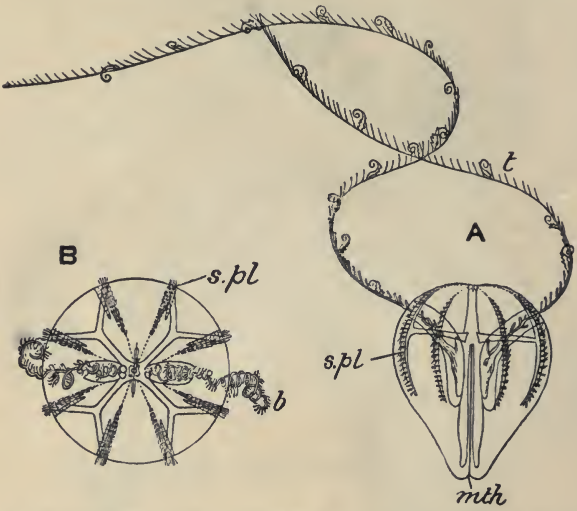

Fig. 65.—**Hormiphora** (*Cydippe*) **plumosa**. A, from the side; B, from the aboral pole. *mth*, mouth; *s. pl*, swimming plates; *t* and *b*, tentacles. Natural size. Mediterranean Sea. (After Chun.)

Laterally there is situated a pair of long slender tentacles, each provided with numerous little tag-like processes, and having its base lodged in a sheath into the interior of which the whole tentacle can be retracted. At one pole, the *oral*, is an opening, the mouth: and at the opposite pole is a pair of minute pores, the *excretory pores*, which are the openings of a pair of canals given off from the enteric cavity. Between the two excretory pores is a remarkable structure, which is the nerve-centre as well as an organ of special sense. The mouth leads into a flattened tube, the gullet, and this again leads into a cavity, the *infundibulum*, which probably corresponds to the stomach of the sea-anemone. From this cavity certain canals are given off.

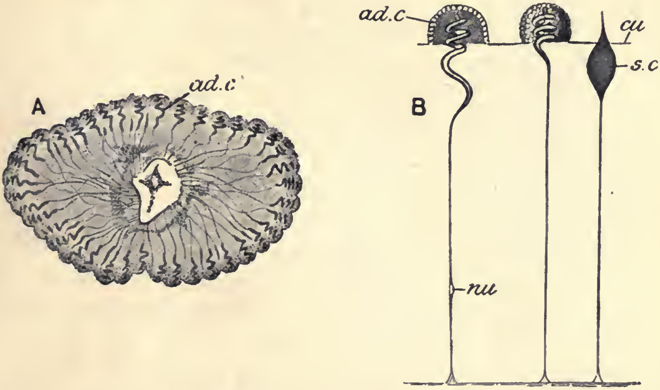

Fig. 66.—**Hormiphora plumosa**. A, transverse section of one of the branches of a tentacle; B, two adhesive cells (*ad c*,) and a sensory cell (*s. c*) highly magnified. *cu*, cuticle; *nu*, nucleus. (After Hertwig and Chun.)

Stinging-capsules are not developed, their place being taken by a number of peculiar cells called *adhesive cells*, with which the branches of the tentacles are covered. An adhesive cell (Fig. 66, B) has a convex surface, produced into small papillæ, which readily adheres to any surface with which it comes in contact, and is with difficulty separated. In the interior of the cell is a spirally coiled filament, the delicate inner end of which can be traced to the muscular axis of the tentacular branch. These spiral threads act as springs, and tend to prevent the adhesive cells from being torn away by the struggles of the captured prey. An allied form is *Pleurobrachia*, very abundant off our shores.

In some of the Ctenophora the body is produced into a pair of lateral lobes. In *Beroë*, instead of being globular, it is more nearly cylindrical, with an extremely wide mouth and gullet, and without tentacles. In the "Venus's girdle" (*Cestus*), it is compressed and almost ribbon-like. All are free-swimming; colonies are never formed; and there is never any kind of skeleton.

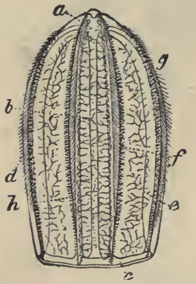

FIG. 67. — **Idyia roseola.** Seen from the broad side, half natural size. *a*, anal opening; *b*, lateral tube; *c*, circular tube; *d*, *e*, *f*, *g*, *h*, rows of paddles. (After Agassiz.)

The Ctenophora are usually perfectly transparent, and quite colourless, save for delicate tints of red, brown, or yellow on the tentacles or on ridges on the inner surface of the gullet. Cestus has, however, a delicate violet hue, and, when irritated, shows a beautiful blue or bluish-green fluorescence; while Beroë is coloured rose-pink, and Idyia is of a brilliant pink. The most primitive form to be found on our coast is *Idyia* (Fig. 67), which is a simple oval sphere, the interior of which forms an immense digestive cavity, in which entire large animals may be engulfed.

SECTION V.—PHYLUM PLATYHELMINTHES

The Platyhelminthes or Flat-worms are a group of animals which, though of a low type of organisation, yet show in many cases a great advance on the Cœlenterata, in the possession of systems of organs of a more or less elaborate character for the carrying on of the various functions. Many are internal parasites of higher animals; others are parasites on the outer surface (external parasites); others again are non-parasitic.

1. THE TREMATODA

A good and easily procurable example of the flat-worms is the Liver-fluke of the sheep (**Distomum hepaticum**), which lives as a parasite in the liver, in the interior of the larger bile-ducts of the infested animal. It is a soft-bodied worm, of flattened, leaf-like shape (Fig. 68), with a triangular process, the *head lobe*, projecting from the broader end. When the liver-fluke is compared with a zooid of *Obelia*, or with a Medusa or a sea-anemone, a striking difference in the general disposition or *symmetry* of the parts is at once recognisable. In the latter, as in the Cœlenterata in general, the prevailing arrangement is a *radial* one, the parts being disposed in a radial manner round the *main axis* of the body, which is an imaginary line running through the middle of the mouth and enteric cavity. In the fluke, on the other hand, the parts are disposed to the right and left of an imaginary median vertical plane, along which the entire animal is capable of being divided into two completely symmetrical, right and left, halves. The type of symmetry here exemplified is termed *bilateral;* it has already been met with in some of the Protozoa, and is characteristic of nearly all animals higher than the Cœlenterata.

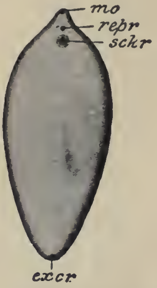

Fig. 68.—Distomum hepaticum. Natural size. *excr*, excretory pore; *mo*, mouth; *repr*, reproductive aperture; *sckr*, posterior sucker.

The broader end of the body is determined as anterior, owing to the mouth and the central part of the nervous system being situated at that extremity. One of the broad flat surfaces is the dorsal, the other the ventral. The mouth (*mo*), situated at the anterior extremity of the head-lobe, is surrounded by a muscular *oral sucker*, and some distance back, on the ventral surface, just behind the head-lobe, is a second much larger *posterior sucker* (*sckr*). Between the two suckers is a median aperture, the *genital opening* (*repr*), through which a curved muscular process, the *cirrus* or *penis*, may be protruded. In the middle of the posterior end of the body is a minute opening, the *excretory pore* (*excr*).

The surface is covered with innumerable minute spinules, but vibratile cilia are absent.

The mouth (Fig. 68, *mo*) leads to a small, bulb-like body, the *pharynx* (Fig. 69, *ph*), with thick muscular walls and a small cavity. From this a short passage, the *œsophagus*, leads to the *intestine*. The latter (*int*) is frequently a very conspicuous structure, owing to its being filled with the dark biliary matter on which the fluke feeds. It divides almost immediately into two main limbs, right and left, and from each of these are given off, both internally and externally, a number of blind branches or *cœca*, those on the inner side being short and simple, while those on the outer side are longer and branched. The two limbs of the intestine, with their branches, thus form a complicated branching

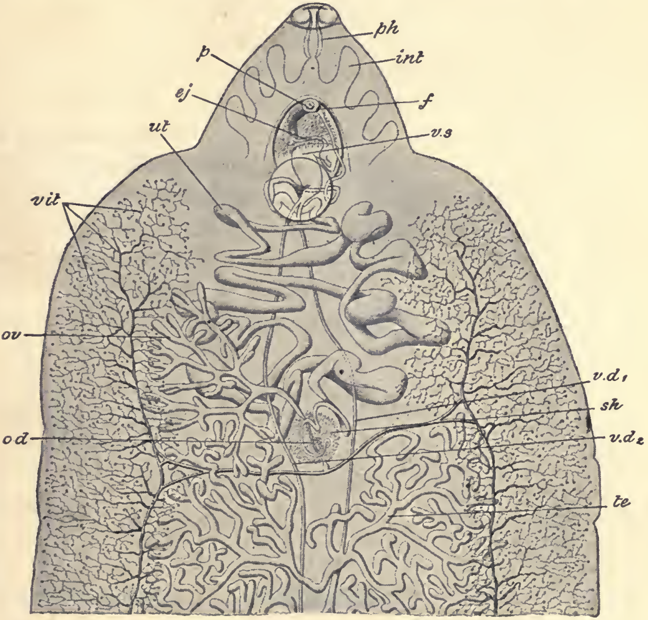

Fig. 69.—**Distomum hepaticum.** Internal organisation. General view of the anterior portion of the body, showing the various systems of organs as seen from the ventral aspect. *ej*, ejaculatory duct; *f*, female reproductive aperture; *int*, anterior portion of the intestine (the rest is not shown); *od*, commencement of oviduct; *ov*, ovary; *p*, penis; *ph*, pharynx; *sh*, shell-gland; *te*, testes; *ut*, uterus; vd_1, left vas deferens; vd_2, right vas deferens; *vit*, lobes of vitelline glands; *vs*, vesicula seminalis. (After Sommer.)

system, the ramifications of which extend throughout the whole of the body. There is no anus, or aperture of communication between the intestine and the exterior, the only external opening of the alimentary system being through the mouth.

A branching system of vessels — the *water-vessels* or vessels of the *excretory system* — ramify throughout the body. A longitudinal *main trunk* opens outwards by means of the excretory pore. In front it gives off four large trunks, each of which branches repeatedly, the branches giving off smaller vessels, and these again still smaller twigs, until we reach a system of extremely fine microscopic vessels, or *capillaries*. Each of these ends internally in a slight enlargement situated in the interior of a large cell, a *flame-cell*, with a bunch of vibratile cilia, or a single thick cilium, in the interior.

The fluke has a nervous system, the arrangement of which partakes of the bilateral symmetry of the body. The central part of this system consists of a ring of nerve matter, which surrounds the œsophagus, and presents two lateral thickenings or ganglia containing nerve-cells, and a single ganglion situated in the middle line below. From this are given off a number of nerves, of which the chief are a pair of lateral cords running back to the posterior end and giving off numerous branches. There are no organs of special sense.

The reproductive organs are constructed on the hermaphrodite plan, *i.e.*, both male and female organs occur in the same individual. The male part of the apparatus consists of testes, sperm-ducts or vasa deferentia, and cirrus. The *testes* (*te*) are two greatly ramified tubes which occupy the middle part of the body, one situated behind the other. From each testis there runs forward a duct, the *vas deferens*, the two vasa deferentia (*v. d*) opening anteriorly into an elongated sac, the *vesicula seminalis* (*v. s*), from which a narrow tube — the *ejaculatory duct* (*ej*) — leads to the male aperture at the extremity of the cirrus. The female part of the apparatus consists of a single *ovary*, an *oviduct*, a *uterus*, *vitelline* or *yolk-glands*, *vitelline ducts* and *shell-glands*. The *ovary* (*ov*) is a branched tube situated on the right side in front of the testes: the branches open into a common duct, the *oviduct* (*od*). The *vitelline glands* (*vit*) consist of very numerous minute rounded follicles, which occupy a considerable zone in the lateral regions of the body. The two main *vitelline ducts*, right and left, run transversely inwards to open into a small sac — the *yolk reservoir*. From this a single median duct passes to join the oviduct. Around the junction is a mass of unicellular *shell-glands* (*sh. gl*). The *uterus* (*ut*) is a wide convoluted tube formed by the union of the median vitelline duct and the oviduct. In front it opens close to the base of the penis. A canal termed the *canal of Laurer* leads from the junction of the oviduct and median vitelline duct to open externally on the dorsal surface of the body.

Each ovum on impregnation becomes surrounded by a mass of vitelline matter or *yolk*, derived from the yolk-glands. It then becomes enclosed in a chitinous shell, the substance of which is derived from the secretion of the shell-glands. The completed egg remains for a time in the uterus; afterwards it is discharged, and, passing down the bile-ducts of the sheep into the intestine, reaches the exterior with the fæces. When it escapes from the egg, the *ciliated embryo*, as it is termed (Fig. 70, *A*), has the form of a somewhat conical body, covered all over with vibratile cilia, and with two spots of pigment, the *eye-spots*, near the broader or anterior end, which is provided with a triangular *head-lobe* (*pap*). There is no vestige of internal organs, with the exception of a pair of flame-cells. The ciliated larva swims about in water, or moves over damp herbage for a time, and perishes unless it happens to reach a pond-snail (*Limnæa*), as a parasite of which it is alone able to enter into the next phase of its life-history. When it meets with the snail, destined to form the *second* or *intermediate host* of the parasite, the embryo bores into it by means of the head-lobe. Established in the interior, it grows rapidly into the form of an elongated sac, the *sporocyst* (Fig. 70, *B*), with an internal cavity. Eventually cells are budded off from the interior of the sporocyst, each of which gives rise to a body called a *redia* (*C*). When fully formed the redia is a cylindrical body, having a mouth leading to a pharynx, followed by a simple sac-like intestine, and a system of excretory vessels. The rediæ, after escaping from the interior of the sporocyst, bud off internally cells which either give rise to a fresh generation of rediæ or to bodies termed *cercariæ*. The latter (*D*) are provided with long tails, with anterior and posterior suckers, a mouth and pharynx, and a bifid intestine. These escape through an aperture in the wall of the redia, and, moving actively by means of their tails, force their way out from the body of the snail. They then, losing the tail, become encysted, attached to blades of grass or herbage. The transference of the larval fluke to its final host, the sheep, is effected if the latter swallow the grass on which the cercaria has become encysted. The young fluke then escapes from the cyst, and forces its way up the bile-ducts to the liver, in which it rapidly grows, and, developing reproductive organs, attains the adult condition.

The liver-fluke is an example of the class of flat-worms known as **Trematoda**. These are all parasitic. Some are internal parasites, and in the adult condition inhabit, for the most part, the enteric canal, the liver, or the lungs of some animal of the Vertebrate or back-boned class (fishes, amphibians, reptiles, birds, or mammals), swallowing the digested food or various secretions of their host. Others are external parasites, living on some part of the outer surface of their host, and feeding on mucus or other secretions of the in-

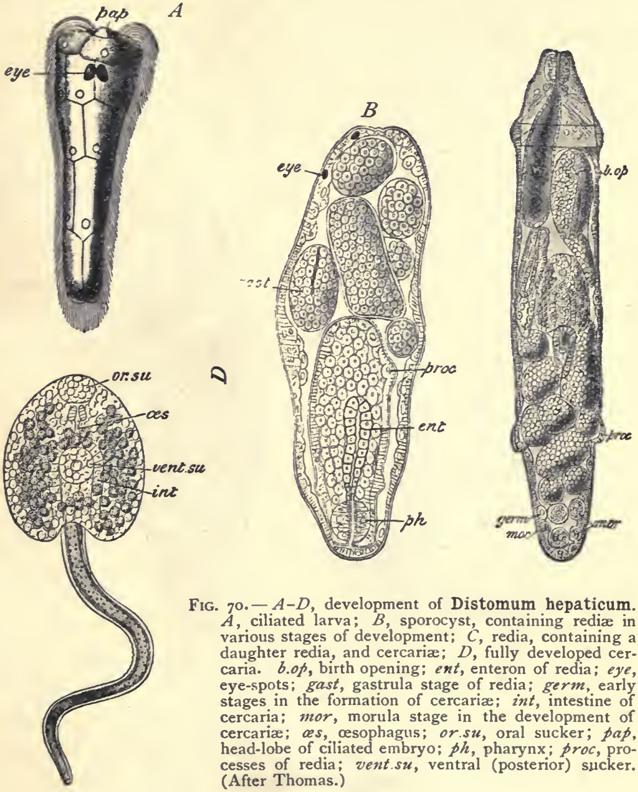

FIG. 70.—*A–D*, development of **Distomum hepaticum.** *A*, ciliated larva; *B*, sporocyst, containing rediæ in various stages of development; *C*, redia, containing a daughter redia, and cercariæ; *D*, fully developed cercaria. *b.op*, birth opening; *ent*, enteron of redia; *eye*, eye-spots; *gast*, gastrula stage of redia; *germ*, early stages in the formation of cercariæ; *int*, intestine of cercaria; *mor*, morula stage in the development of cercariæ; *œs*, œsophagus; *or.su*, oral sucker; *pap*, head-lobe of ciliated embryo; *ph*, pharynx; *proc*, processes of redia; *vent.su*, ventral (posterior) sucker. (After Thomas.)

tegument. The leaf-like form exemplified in the liver-fluke prevails in most (Fig. 71), but a more elongated form sometimes occurs. The anterior end is distinguished from the posterior by its shape, by the arrangement of the suckers, and, in many of those Trematodes that are external parasites, by the presence of eyes. Suckers are universal in their occurrence. They are always ventrally placed, their chief function being to fix the parasite to the surface of its host in such a way as to facilitate the taking in by the mouth of animal juices and epithelial *débris*. Their number and arrangement vary considerably. There are nearly always present an anterior set (or, as in the liver-fluke, a single anterior sucker surrounding the mouth), and a posterior set or a single large posterior sucker. There

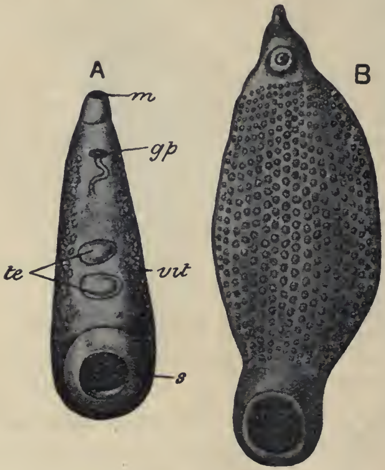

FIG. 71.—**Trematodes.** A, *Amphistomum;* B, *Homalogaster.* *gp*, genital aperture; *m*, mouth; *s*, posterior sucker; *te*, testes; *vit*, vitelline glands. (After M. Braun.)

are no cilia on the surface, and a well-developed enteric canal is always present.

A remarkable series of metamorphoses, such as that which has been described in the liver-fluke, is characteristic of the internally parasitic forms; in the *ectoparasitic* or externally parasitic Trematodes development is direct, the young animal when it escapes from the egg differing little from the adult except in size.

2. THE TURBELLARIA

The **Turbellaria** are a class of flat-worms which, though for the most part non-parasitic, resemble the Trematodes very closely, the chief difference being the presence of a coating of vibrating cilia, and the absence, in the majority, of suckers. The leaf form is the prevailing one (Fig. 72), but in many the body is elongated and ribbon-like, or subcylindrical. In some the anterior end is retractile, and may be everted as

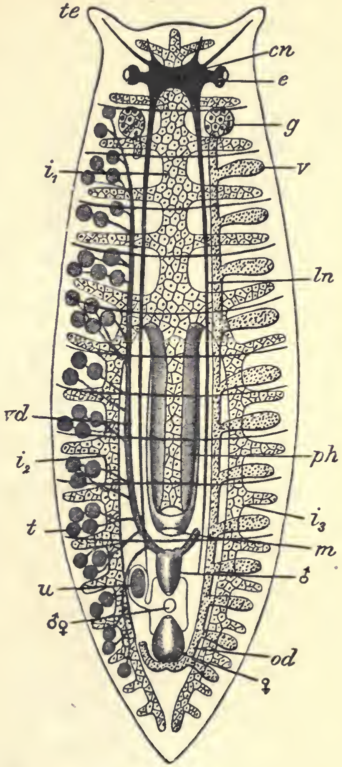

Fig. 72. — General plan of the structure of a Triclad Turbellarian. *cn*, brain; *e*, eye; *g*, ovary; i_1, median limb of the intestine; i_2, left limb; i_3, right limb; *ln*, longitudinal nerve-cord; *m*, mouth; *od*, oviduct; *ph*, pharynx; *t*, testes; *te*, tentacles; *vd*, vas deferens; *u*, uterus; ♂, ejaculatory duct; ♀, vagina; ♂♀, common genital aperture. (After Von Graff.)

a proboscis. The mouth is never at the extreme anterior end, but is always ventrally placed, sometimes behind the middle. A few multiply by budding, and these may give rise to chains of individuals, which subsequently become separated. In the lowest Turbellaria the intestine is represented merely by a nucleated mass of protoplasm; in others it is a simple sac; in the majority it is branched. The general structure of the other internal organs very closely resembles that of the corresponding parts in the Trematodes.

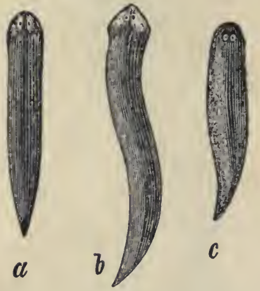

Fig. 73.—*Planaria polychroa* (*a*), *lugubris* (*b*), *torva* (*c*), about thrice the natural size. (After Schmidt, from Claus.)

Turbellaria occur in the sea, in fresh water, and also in damp localities on land. The great majority are non-parasitic, their food consisting of minute aquatic animals and plants of various kinds. An example is *Planaria torva* of our fresh-water pools and streams (Fig. 73, *c*).

3. THE CESTODA

The class **Cestoda** or tape-worms are all internal parasites, and in the adult condition live in the enteric canal of vertebrates. The tape-worms are much more completely adapted to a life of parasitism than the Trematodes: they have no digestive system, and are nourished by the imbibition, through the general surface, of liquid nutriment derived from the digested food of the vertebrate host. The shape of a typical tape-worm is widely different from that of a trematode. A tape-worm (Fig. 74) is flattened like a trematode, but is extremely elongated, the length being

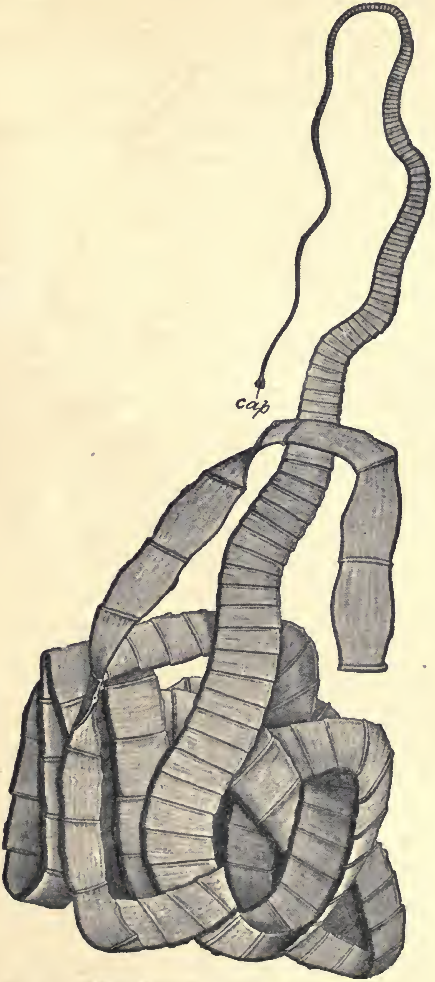

FIG. 74. — **Tænia solium.** Human tape-worm. Entire specimen reduced. *cap*, head. (After Leuckart.)

many times, often hundreds of times, the greatest breadth, so that the animal assumes the form of a long, narrow ribbon or tape. This ribbon is not continuous, but is made up of a string of segments or *proglottides*. Towards one end the body becomes narrower, terminating in a rounded knob—the head or *scolex*. On the head (Fig. 75) is a circlet of hooks borne on a rounded prominence, the *rostellum*, which is capable of being protruded and retracted to a certain extent; at the sides are four suckers. By means of these hooks and suckers the head is attached to the wall of the intestine of the host, the elongated body lying free in its interior. The part of the body just behind the head (*neck*) is not divided into segments. The most anterior segments are much shorter than those further back, and not so distinctly separated off from one another. The surface is devoid of cilia, as in the Trematodes. A *digestive cavity* is, as already stated, absent; but there is a distinct *nervous* system, and a system of *water-vessels* with flame-cells. In the posterior region of the body each proglottis (Fig. 76) is found to contain a complete set of hermaphrodite *reproductive organs* similar in general plan to those of the liver-fluke. The ova, when fertilised, are enclosed in a chitinoid shell, and received into a uterus. In the most posterior segments the *uterus* is a large branched tube distended with enormous quantities of these eggs, and the other parts of the reproductive apparatus have become absorbed. These "ripe" proglottides, as they are termed, drop off, one by one, from the pos-

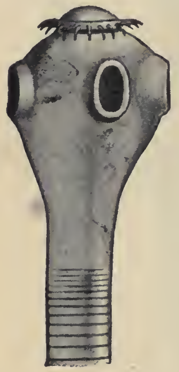

Fig. 75.—Head of **Tænia solium**, magnified. (After Leuckart.)

terior end, and reach the exterior with the fæces of the host. At the same time new proglottides are constantly being formed by the appearance of new ring-like grooves behind the neck region. This dropping off of ripe proglottides from the posterior end, and the formation of new ones behind the neck, results in a gradual shifting backwards of the proglottides. As each proglottis passes backwards from its point of origin, it gradually develops the various parts of the reproductive apparatus in its interior, until, when it has reached the posterior region, it possesses a complete set of reproductive organs, and, as it reaches the extreme posterior end, it has become ripe, *i.e.*, has its uterus distended with eggs.

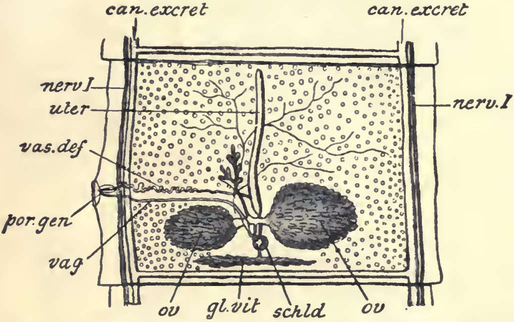

FIG. 76.—A proglottis of **Tænia solium** with mature reproductive apparatus. *can. excret*, longitudinal excretory canals with transverse connecting vessels; *gl. vit*, vitelline glands; *nerv. l*, longitudinal nerves; *ov*, *ov*, ovaries; *por. gen*, genital pore; *schld*, shell-glands; *uter*, uterus; *vag*, vagina; *vas. def*, vas deferens. The numerous small round bodies are the lobes of the testes. (After Leuckart.)

In the interior of each of the eggs in the ripe proglottides is an embryo consisting of a rounded mass of cells bearing six chitinoid hooks—the six-hooked or *hexacanth* embryo (Fig. 77, A). After the egg has been discharged from the free proglottis, it has to reach the enteric canal of a second kind of animal — a second or intermediate host — in order that the embryo may be enabled to enter the next phase of its life-history. In the case of some tape-worms, this second or intermediate host is, like the first or permanent host, a vertebrate animal: in the case of others it is some invertebrate animal such as an earth-worm, a centipede, or an insect. This transference of the hexacanth embryo to the second host is a passive migration, not an active one, as in

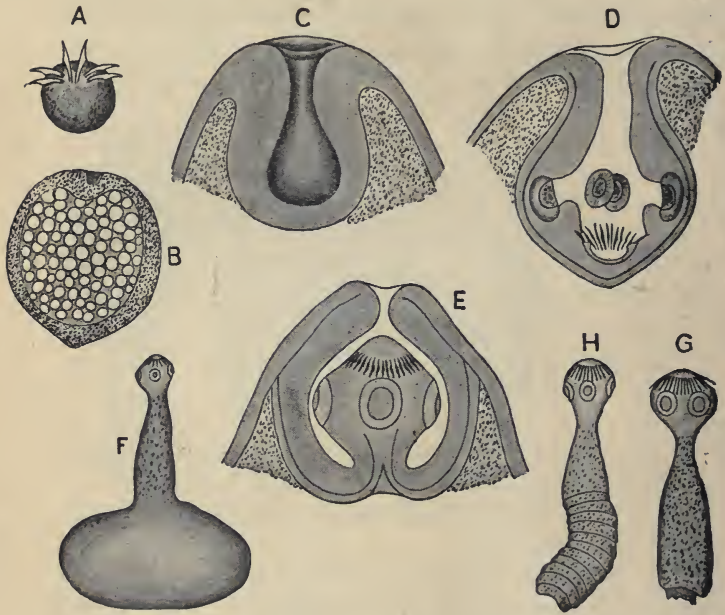

Fig. 77. — Development of **Tape-worm.** A, hexacanth embryo; B, Proscolex of *Tænia saginata;* C–E, stages in the formation of the scolex of the same; C, the invagination before the hooks and suckers have become developed; D, after the appearance of the hooks and suckers; E, partly evaginated; F, fully evaginated scolex of *T. solium* with caudal vesicle; G, scolex of *T. serrata* with the remains of the vesicle; H, young tape-worm of *T. serrata.* (After Leuckart.)

the case of the ciliated embryo of the Trematodes, the egg being received into the enteric canal of the second host with the water or food. The digestive fluids of this second host dissolve the egg-shell and set free the contained embryo, which bores its way by means of its hooks to some part of the body in which it is destined to pass through the next phase of its life-history, and there becomes encysted (B). The phase which follows presents two main varieties. In cases in which the second host is an invertebrate animal, the hooked embryo develops into a form to which the name of *Cysticercoid* is given; when, on the other hand, the intermediate host is a vertebrate, the form assumed is nearly always that termed *Cysticercus* or bladder-worm. In both cases a tape-worm head is developed, with the rostellum, hooks, and suckers of the adult. In the Cysticercus (C–H) this is formed from the wall of a relatively large cyst or bladder into which the hooked embryo develops.

In a very small number both of Cysticercoids and of Cysticerci more than one tape-worm head is formed. Thus *Tænia cænurus* of the dog has a bladder-worm stage occurring in the sheep and rabbit, which gives rise to several tape-worm heads. But the most striking instance of multiple production of tape-worm heads in a bladder-worm is *Tænia echinococcus*, well known as the cause of the disease termed *hydatids*, common in man and in various domestic animals. In this case the hooked embryo develops into a large *mother-cyst*, from the interior of which *daughter-cysts* are budded off. Eventually from the walls of these daughter-cysts (Fig. 78) are formed numerous tape-worm heads.

The transference to the first or final host is effected by the second or intermediate host, or the part of it containing the Cyticercus or Cysticercoid, being taken into the enteric canal of the final host. Sometimes, if the intermediate host is a small animal, such as a water-flea, this may take place "accidentally"; in other cases the intermediate host actually forms the food of the final host. Thus, to give two instances, a Cysticercoid having as an intermediate host an earth-worm is taken with the latter into the enteric canal of a sea-gull — its final host; a Cysticercus which occurs in the liver of rats and mice is received into the enteric canal of the cat. In this way the Cysticercus or Cysticercoid is set free in the enteric canal of the final host; the tape-worm head becomes attached by means of its hooks and suckers to the wall of the intestine, and the long segmented body of the tape-worm is developed behind.

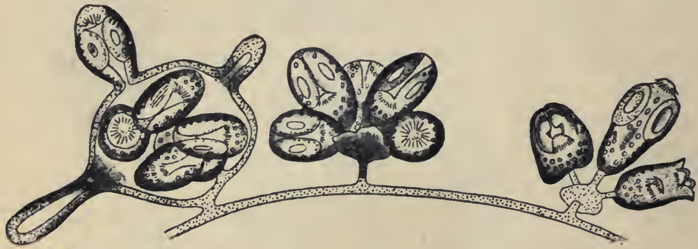

FIG. 78.—Cyst of **Tænia echinococcus** with the developing daughter-cyst and scolices. (After Leuckart.)

The commonest human Cestode parasites in the United States and Canada are *Tænia solium* and *T. saginata* (*T. mediocanellata*), the latter being the more common pest. The Cysticercus stage of the former occurs chiefly in the flesh of the pig; that of the latter in the flesh of the ox; and the relative prevalence of these two tape-worms in different countries varies with the habits of the people with regard to flesh-eating: where more swine's flesh is eaten in an imperfectly cooked state *Tænia solium* is the more prevalent, where more beef, *T. saginata*.

Bothriocephalus latus, a very large tape-worm without hooks, is a common human parasite in eastern countries. Its Cysticercus occurs in the pike and certain other fresh-water fishes. It has not become endemic, or naturalized, in the United States.

4. THE NEMERTINEA

The **Nemerteans** are non-parasitic, unsegmented worms, most of which are marine, only a few forms living on land or in fresh water. They are commonly looked upon as nearly related to the Turbellaria, and were formerly included in that class; but they are in some respects higher in organisation than the Turbellaria, and they exhibit certain special features distinguishing them from the rest of the lower worms.

The body (Figs. 79 and 80) is narrow and elongated, cylindrical or depressed, unsegmented, and devoid of appendages. In length it varies, in different species, from a few millimetres to as much as ten metres. The entire surface is covered with vibratile cilia.

The *mouth* (*m*) is at or near the anterior extremity on the ventral aspect. Close to it above there is an opening through which can be protruded a very long muscular organ, the *proboscis* (*pr*), the possession of which is one of the most characteristic features of this class of worms. The proboscis is hollow: when it is extended to its utmost, a part still remains which is not capable of being everted, and at the junction between the eversible and non-eversible parts, *i.e.*, at the extremity of the organ when it is fully protruded, there is in many of the Nemerteans a pointed or serrated *stylet* (Fig. 80, *st*), which probably permits of the proboscis being used as a weapon: when a stylet is absent, the surface of the extremity is sometimes abundantly provided with *stinging-capsules;* sometimes it is beset with glandular *adhesive papillæ.* The proboscis is capable of

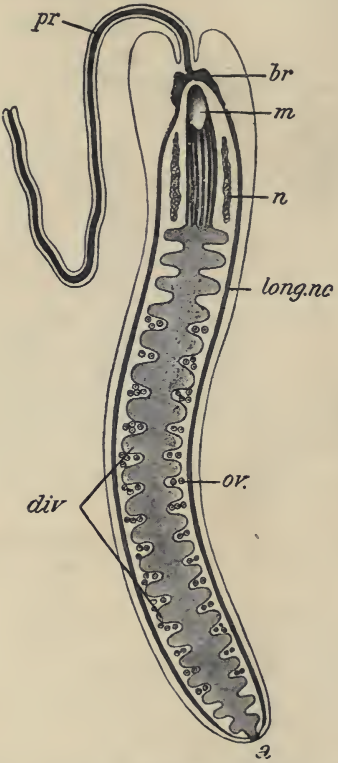

FIG. 79. — Diagram of the organs of a Nemertine, from below. *a*, anus; *br*, brain; *div*, cœca; *long. nc*, longitudinal nerve-cords; *m*, mouth; *n*, nephridia; *ov*, ovaries; *pr*, probosis. (After Hubrecht.)

being retracted within the interior of an investing sheath, the *proboscis sheath.*

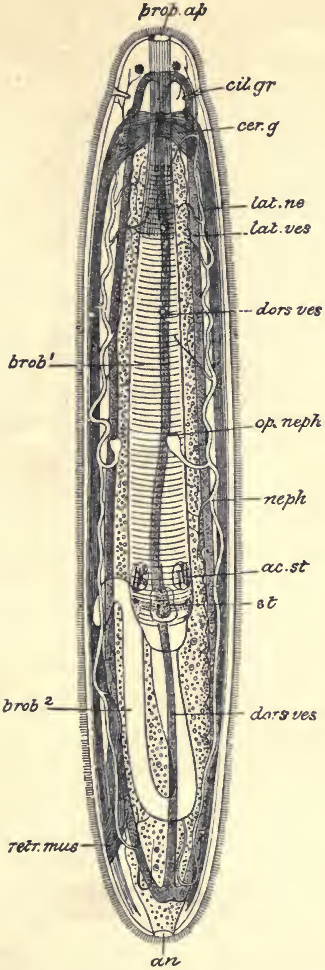
prob. ap
cil. gr
cer. g
lat. ne
lat. ves
dors ves
prob¹
op. neph
neph
ac. st
st
prob²
dors ves
retr. mus
an

FIG. 80. — **Tetrastemma**. General view of the internal organs. *an*, anus; *ac. st*, accessory stylet; *cer. g*, brain; *cil. gr*, ciliated groove; *dors. ves*, dorsal vessel; *lat. ne*, lateral nerve; *lat. ves*, lateral vessel; *neph*, nephridium; *op. neph*, nephridial aperture; *prob*¹, eversible part of proboscis; *prob*², non-eversible part of proboscis; *prob. ap*, aperture for the protrusion of the proboscis; *retr. mus*, retractor muscle of the proboscis; *st*, stylet. (From Hatschek's *Lehrbuch.*)

The *alimentary canal* (Fig. 79) is a simple tube distinguishable into *œsophagus* with longitudinally folded walls, and *intestine* with lateral *cœca* (*div*). It ends in an *anal opening* (*a*) situated near the posterior extremity of the body.

The Nemerteans possess a system of *blood-vessels* with well-defined walls formed of an epithelium and a layer of muscle. There are three principal longitudinal trunks — a *median dorsal* and two *lateral*. The blood follows no regular course through the vessels, but is moved about by the muscular contractions of the body.

The *excretory vessels* of the Platyhelminthes are represented in the Nemertine worms by a pair of greatly coiled and branched tubes (Fig. 80, *neph*), opening on the exterior; the fine terminal branches of the system are provided with *ciliary flames*, and cilia occur also in the course of the vessels themselves.

The *nervous system* is in some respects more highly developed than in the *Turbellaria*. The *brain* (Fig. 80, *cer. g*) is composed of two large ganglia with lobed surfaces, connected together by two *commissures*, dorsal and ventral, between which pass the proboscis and its sheath. From the brain pass backwards a pair of thick nerves which run throughout the length of the body.

Eyes are present in the majority of Nemerteans, and in the most highly organised species occur in considerable numbers.

Most species are *diœcious*. The *ovaries* (Fig. 79, *ov*) and *testes* are situated in the intervals between the intestinal cœca. The ovary or testis is a sac, the cells lining which give rise to ova or spermatozoa; when these are mature each sac opens by means of a narrow duct leading to the dorsal surface, where it opens by a pore.

SECTION VI.—PHYLUM NEMATHELMINTHES

THE **Nemathelminthes** or round-worms are so named because the body instead of being compressed from above downwards, as in the flat-worms, is rounded, *i.e.*, cylindrical. The majority of the members of the phylum belong to the class of the **Nematoda** or round-worms in a more restricted sense. A good example of these is the common round-worm of man (**Ascaris lumbricoides**), which is a common parasite in the human intestine; or the nearly allied **Ascaris suilla** of the pig. When fresh the animal is of a light yellowish-brown colour; it is marked with four longitudinal streaks, two of which, very narrow and pure white in the living worm, are respectively dorsal and ventral in position, and are called the *dorsal* (Fig. 81, *d. l*) and *ventral* (*v. l*) *lines:* the other two are lateral in position, thicker than the former and brown in colour, and are distinguished as the *lateral lines*. The *mouth* is anterior and terminal in position, and is bounded by three lobes, or *lips*, one median dorsal (*d. lp*), the other two ventro-lateral (*v. lp*). A very minute aperture on the ventral side, about two millimetres from the anterior end, is the *excretory pore* (*ex. p*). At about the same distance from the pointed and down-turned posterior end is a transverse aperture with thickened lips, the *anus* (*an*), which in the male serves also as a reproductive aperture, and gives exit to a pair of needle-like chitinoid bodies, the *penial setæ* (*pn. s*). In the female the reproductive aperture or *gonopore* is separated from the anus, and is situated on the ventral surface about one-third of the length of the body from the anterior end (Fig. 82, *gnp*).

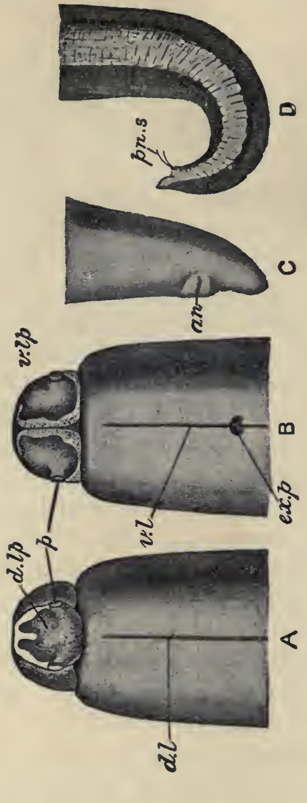

Fig. 81.—**Ascaris lumbricoides.** A, anterior end from above; B, the same from below; C, posterior end of female; D, of male, side view. *an*, anus; *d. lp*, dorsal lip; *d. l*, dorsal line; *ex. p*, excretory pore; *p*, papillæ; *pn. s*, penial setæ; *v. l*, ventral line; *v. lp*, ventral lip. (After Leuckart.)

The outer surface of the body is furnished by a delicate, transparent, elastic membrane, of a chitinoid nature, the *cuticle.* It is wrinkled transversely so as to give the animal a segmented appearance. Beneath the cuticle is a protoplasmic layer containing scattered nuclei and longitudinal fibres, and representing a *syncytial ectoderm*, *i.e.*, an ectoderm in which the cell-bodies are not differentiated, and its cellular nature is recognisable only by the nuclei.

Beneath the ectoderm is a single layer of *muscular fibres* of peculiar structure, arranged longitudinally, and bounding the body-cavity.

The muscular layer is not continuous, but is divided into four longitudinal bands or quadrants, two dorso-lateral and two ventro-lateral, owing to the fact that at the dorsal, ventral, and lateral lines the ectoderm undergoes a great thickening and projects inwards, between the muscles, in the form of four longitudinal ridges. It is this arrangement that gives rise to the lines seen externally.

The mouth leads into the anterior division of the enteric

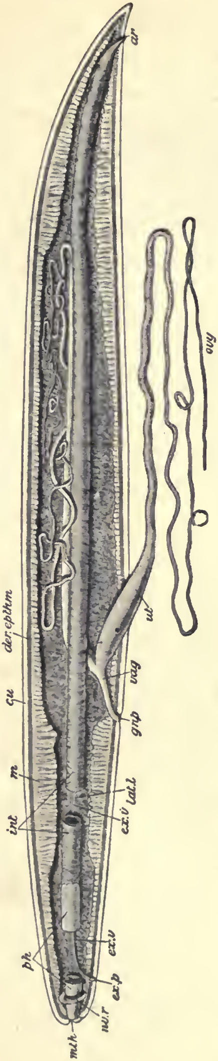

FIG. 82.—**Ascaris lumbricoides.** Semi-diagrammatic dissection of the female. *an*, anus; *cu*, cuticle; *der. epthm*, deric epithelium; *ex. p*, excretory pore; *ex. v*, excretory vessel; *gnp*, gonopore; *int*, intestine partly cut away; *lat. l*, lateral line; *m*, muscular layer; *mth*, mouth; *nv. r*, nerve-ring; *ovy*, ovary, that of the right side in situ, the left spread out; *ph*, pharynx, partly cut away; *ut*, uterus.

canal, the *pharynx* or stomodæum (Fig. 82, *ph*), with very muscular walls. Posteriorly the pharynx opens into the *intestine* (*int*), a thin walled tube, flattened from above downwards. Posteriorly the intestine narrows considerably to form the short *rectum*, which opens externally by the anus (*an*). The food, consisting of the semi-fluid contents of the intestine of the host, is sucked in by movements of the pharynx, and is then absorbed into the system through the walls of the intestine. The food being already digested by the host, there is no need of digestive gland-cells such as occur in animals which prepare their own food for absorption.

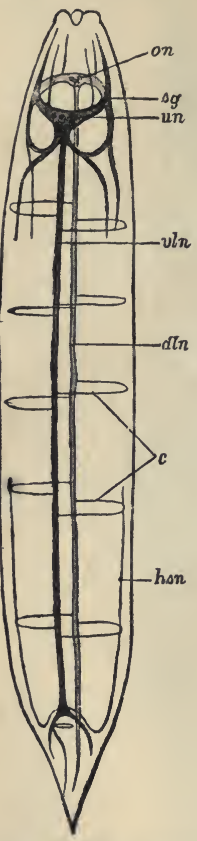

FIG. 83. — Diagram of nervous system of Nematoda. *c*, commissures; *dln*, dorsal nerve; *hsn*, posterior lateral nerve; *on*, upper and *un*, under portion of nerve-ring; *sg*, lateral swellings; *vln*, ventral nerve. (From Lang, after Bütschli.)

Between the enteric canal and the body-wall is a distinct space, the cœlome or *body-cavity*, containing a clear fluid.

The excretory system presents a certain resemblance to that of Platodes. It consists of two longitudinal canals (*ex. v*), one in each lateral line. Anteriorly they pass to the ventral surface, unite with one another, and open by the minute excretory pore (*ex. p*) already noticed.

The *nervous system* consists of a ring (*nv. r*) surrounding the pharynx and giving off six nerves forwards and six backwards (Fig. 83). Of the latter, two are of a considerable size and run in the dorsal and ventral lines respectively (*dln*, *vln*).

The reproductive organs are formed on a peculiar and very characteristic pattern. The *testis* (Fig. 84, *ts*) is a long coiled thread, occupying a considerable portion of the body-cavity. At its posterior end it is continuous with the *vas deferens*. The vas deferens, in its turn, becomes continuous with a wide canal, the *vesicula seminalis* (*vs. sem*), which opens by a short, narrow, muscular tube, the *ductus ejaculatorius*, into the rectum. Behind the rectum, and opening into its dorsal wall, are paired muscular sacs (*s*) containing the *penial setæ* (*p. ns*) already noticed. The anterior end of the testis consists of a solid mass of sexual cells; passing backwards there is found a cord or *rachis* occupying the axis of the tube and

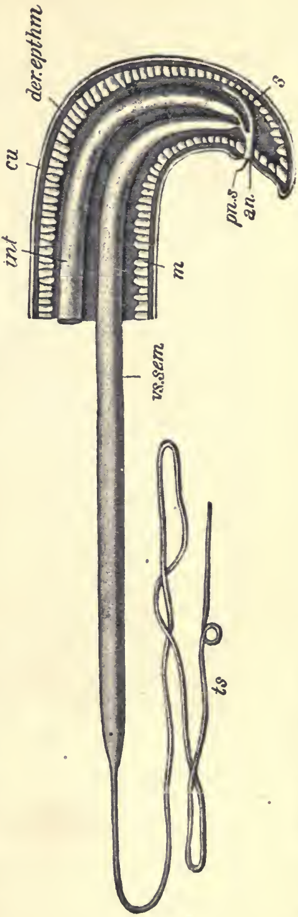

Fig. 84.—**Ascaris lumbricoides**, posterior extremity of male, dissected. *an*, anus; *cu*, cuticle; *der epthm*, epidermis; *m*, muscular layer; *pn. s*, penial seta; *s*, sacs containing penial seta; *ts*, testis; *vs. sem*, vesicula seminalis.

having the sperm-cells attached to it; still further back the sperms become gradually differentiated, and are finally set free in the vas deferens.

The organs of the female (Fig. 82) resemble those of the male, but are double instead of single. There are two coiled, thread-like *ovaries* (*ovy*), each passing insensibly into a uterus (*ut*). In the ovary, as in the testis, the eggs are developed in connection with an axial cord or rachis. The two uteri unite in a short muscular *vagina* (*vag*) which opens, as already seen, on the ventral surface of the body (*gnp*) at about one-third of the entire length from the head.

The **Nematodes** in general vary greatly in size, from about 1 mm. or less to two metres (six feet) in the case of the Guinea-worm, the length always being great in proportion to the diameter, and the body being always bluntly pointed at the anterior end, and either pointed or forked posteriorly.

The mouth is frequently armed with spines by means of which the worms draw blood from the intestinal blood-vessels of their host. Many free-living forms have a sharp stylet for piercing the tissues of the plants on which they feed, and a suctorial apparatus for absorbing their juices.

The nervous system has in most the same general structure as in Ascaris, and the same holds good of the reproductive apparatus. A few are hermaphrodite, but, instead of a double set of reproductive organs as in Platyhelminthes, they have organs similar to those of the female Ascaris, the gonads producing first sperms and afterwards ova.

One of the most terrible parasites of man is a nematode called *Trichina spiralis* (Fig. 85), a minute worm, the male (C) a little over 1 mm. ($\frac{1}{18}$ inch) in length, the female (B) about 3 mm. ($\frac{1}{8}$ inch). In the adult or sexual condition it lives in the intestine of man, the pig, and other mammals. Internal impregnation takes place, the eggs develop in the

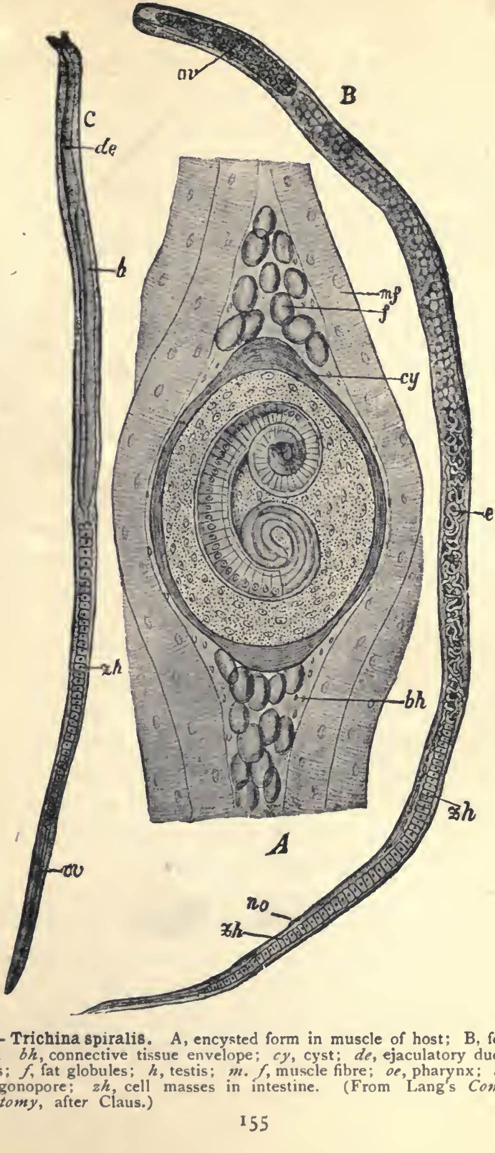

FIG. 85. — **Trichina spiralis.** A, encysted form in muscle of host; B, female; C, male. *bh*, connective tissue envelope; *cy*, cyst; *de*, ejaculatory duct; *e*, embryos; *f*, fat globules; *h*, testis; *m. f*, muscle fibre; *oe*, pharynx; *ov*, ovary; *wo*, gonopore; *zh*, cell masses in intestine. (From Lang's *Comparative Anatomy*, after Claus.)

uterus of the female, and the minute young (B, *e*), to the number of at least about a thousand, are born alive. Soon after birth the young worms migrate through the walls of the intestine and reach the voluntary muscles of the host, such as those of the limbs, back, tongue, etc. Each worm enters a muscle-fibre and coils itself up in the muscle-substances (A); a spindle-shaped cyst (*cy*) is formed round it, and the muscle undergoes more or less degeneration. This process gives rise to various morbid symptoms in the host, but, after some months the cysts become calcified and the danger to the infected individual is over. In order that further development of the encysted and sexless Trichinæ should take place, it is necessary for the infected flesh of the host to be eaten by another animal in which the worm is capable of living, *e.g.*, that of man by pig or rat, or that of a pig by man. When this is done the cysts are dissolved by the digestive juices, the worms escape, develop reproductive organs, and copulate, the young migrating into the muscles and producing the disease as before.

It will be noticed that in this case the parasite is able to exist in various hosts, and that both sexual and asexual stages are passed through in the same host, dispersal of the species taking place by the flesh of an infected animal being eaten by another, either of the same or of a different species.

The female Guinea-worm (*Dracunculus medinensis*) attains a length of 30–200 cm. (1–6 feet), and lives in the subcutaneous connective tissue of man. The eggs develop in the uterus, and the newborn young pass out of the body of the host through abscesses caused by the presence of the parasite. If, as must often be the case, they escape into water, they make their way into the body of a water-flea (*Cyclops*), and in this condition probably reach their human host once more in his unfiltered drinking water.

SECTION VII.—PHYLUM ECHINODERMATA

THE starfishes, brittle-stars, sea-urchins, feather-stars, and their allies, many of which are familiar objects on the seashore, are grouped together as the phylum Echinodermata. Even a superficial comparison of a starfish, a brittle-star, and a sea-urchin will reveal unmistakable points of agreement. All have a hard surface more or less abundantly provided with pointed spines: in all the symmetry is distinctly radial; and, if the animals are examined in the living condition while immersed in sea-water, it will be found that all are provided with rows of soft retractile tubular appendages acting in the starfish and sea-urchin as the organs of locomotion by means of which the animal creeps slowly along. Examination of the external structure shows, as will presently become evident, that the resemblance is not a merely superficial one, but extends to all the systems of internal organs.

1. THE ASTEROIDEA

The body of a starfish, such as the common English red starfish, **Asterias rubens**, or *A. vulgaris*, of our American coast, is enclosed in a tough, hard integument, containing numerous plates or *ossicles*, as they are termed, of calcareous material. This exoskeleton is not completely rigid in the fresh condition, but presents a certain limited degree of flexibility. The body (Fig. 86) is star-shaped, consisting of a central part, the *central disc*, and five symmetrically arranged processes, the *arms* or *rays*, which, broad at the base, taper slightly towards their outer extremities. There are two surfaces, one the *dorsal* or *abactinal*, directed upwards in the natural position of the living animal; the other, the *ventral* or *actinal*, directed downwards. The dorsal surface is convex, the ventral flat; the colour of the former is much darker than that of the latter.

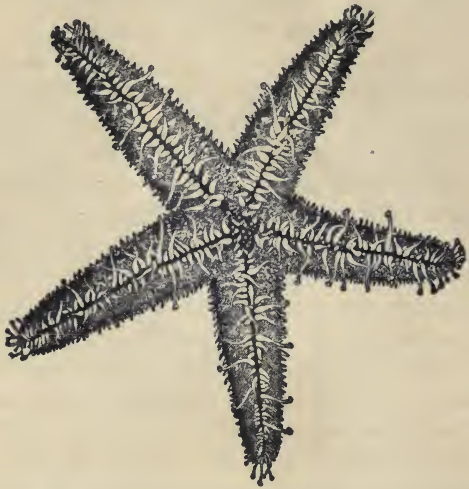

FIG 86. — **Starfish.** General view of the ventral surface, showing the tube-feet. (From Leuckart and Nitsche's Diagrams.)

In the centre of the ventral surface (see Fig. 92) is a five-rayed aperture, the *actinostome*, and running out from this in a radiating manner are five narrow grooves, each running along the middle of the ventral surface of one of the arms to its extremity. Bordering each of the ambulacral grooves there are either two or three rows of movable calcareous spines, the *ambulacral spines*. External to the ambulacral spines are additional rows of stout spines, which are not movable.

On the convex dorsal surface there are a number of short, stout spines arranged in irregular rows parallel with the long axes of the rays. These are supported on irregularly shaped ossicles buried in the integument. In the soft interspaces between the ossicles are a number of minute pores, the *dermal pores*, scarcely visible without the aid of a lens. Through each of these pores projects a very soft filiform process, one of the *dermal branchiæ* or *papulæ* (Fig. 88, *Resp. cæ*), which is capable of being entirely retracted.

Very nearly, though not quite, in the centre of the dorsal surface is an aperture, the *anus* (*an*), wide enough to admit of the passage of a moderately stout pin. On the same surface, midway between the bases of the two rays, is a flat, nearly circular plate, the surface of which is marked by a number of radiating, narrow, straight, or slightly wavy grooves: this is the *madreporite*.

Attached to the spines of the ventral surface, in the intervals between them, and in the intervals between the spines on the dorsal surface, are a number of very small, almost microscopic, bodies, which are termed the *pedicellariæ* (Fig. 88, *Ped*). Each of these is supported on a longer or shorter flexible stalk, and consists of three calcareous pieces, a *basilar* piece at the extremity of the stalk, and two *jaws*, which are movably articulated with the basilar piece, and are capable of being moved by a certain set of muscular fibres, so as to open and close on one another like the jaws of a bird.

In a well-preserved specimen there will be seen in each of the ambulacral grooves two double rows of soft tubular bodies ending in sucker-like extremities; these are the *tube-feet* (Figs. 86, 88, *T. F*), of which, in Asterias, there are four rows in each arm. In a living specimen they will be seen to act as the locomotive organs of the animal. They are capable of being greatly extended, and when the starfish is moving along, it will be observed to do so by the tube-feet being extended outwards and forwards (*i.e.*, in the direction in which the animal is moving), their extremities becoming fixed by the suckers, and then the whole tube-foot contracting so as to draw the body forward; the hold of the sucker then becomes relaxed, the tube-foot is stretched forwards again, and so on. The action of all the tube-feet, extending and contracting in this way, results in the steady progress of the starfish over the surface. With the aid of the tube-feet the starfish is also able to right itself if it is turned over on its back.

At the extremity of each of the ambulacral grooves is to be distinguished a small bright red spot, the *eye* (Fig. 88, A, *oc*), and over it a median process, the *tentacle* (*t*), similar to the tube-feet but smaller and without the terminal sucker. The tentacles have been ascertained by experiment to be olfactory organs, the starfish being guided to its food much more by this means than by the sense of sight. If one of the arms be cut across transversely (Fig. 87 and Fig. 88, B) and the cut surface examined, the dorsal part of the thick, hard wall of the arm will present the appearance of an arch (with its convexity upwards), and the ventral part the form of an inverted V, the ends of the limbs of which are connected with the ventral ends of the dorsal arch by a very short, flat, horizontal portion. Enclosed by these parts is a space, a part of the cœlome or *body-cavity*, and below, between the two arms of the V, is the ambulacral groove.

The dorsal arch is supported by a number of irregular ossicles. The V-shaped ventral part of the body-wall — *i.e.*, the walls of the ambulacral groove — is supported by two rows of elongated ossicles, the *ambulacral ossicles* (Fig. 88, *Amb. os*), which meet together at the apex or summit of the groove like the rafters supporting the roof of a house, but with a movable articulation allowing of separation or approximation of the two rows so as to open or close the groove. Between the ambulacral ossicles of each row are a series of oval openings, the *ambulacral pores*, one between each contiguous pair of ossicles. In the ventral groove lie the tube-feet (*t. f*). Each tube-foot is found to correspond to one of the ambulacral pores. When the tube-foot is drawn upon, it is seen to be continuous with one of

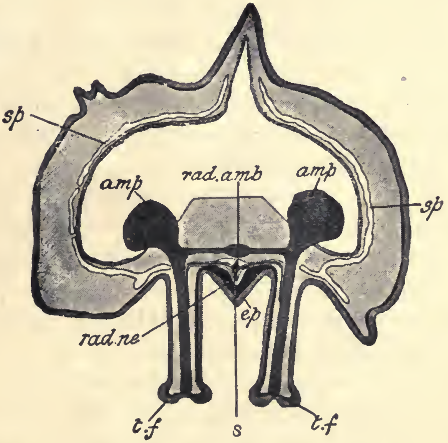

FIG. 87. — **Starfish.** Vertical section through an arm. *amp*, ampullæ; *ep.* epidermis; *rad. amb*, radial vessel of the ambulacral system; *s* points to the septum dividing the blood-vessel into two parts; *rad. ne*, radial nerve of the epidermal system; *sp*, spaces in mesoderm of body-wall; *t. f*, tube-feet. (From Leuckart, after Hamann.)

a series of little bladder-like bodies, the *ampullæ*, which lie on the other side of the ambulacral ossicles, *i.e.*, in the cavity of the arms. When one of them is squeezed the corresponding tube-foot is distended and protruded, the cavities of the tube-foot and the ampulla being in communication by means of a narrow canal running through the ambulacral pore; and it is in this way that the foot is protruded in the living animal. The corresponding ampulla being contracted by the contraction of the muscular fibres in its walls, the contained fluid is injected into the tube-foot and causes its protrusion.

Running along the ambulacral groove, immediately below where the ambulacral ossicles of opposite sides articulate, is a fine tube, the *radial ambulacral vessel* (Fig. 87, *rad. amb;* Fig. 88, B, *Rad. Amb. V;* Fig. 90, *r*), which appears in the transverse section as a small rounded aperture. From this short side branches (Fig. 90 *r′*) pass out on either side to open into the bases of the tube-feet. Below the radial ambulacral vessel is a median thickening of the integument covering the ambulacral groove; this marks the position of the *radial nerve* (Figs. 87 and 88, *Rad. ne*) of the *epidermal nervous system*, and is traceable as a narrow thickened band running throughout the length of the groove, and terminating in the eye at its extremity, while internally it becomes continuous with one of the angles of a pentagonal thickening of a similar character, the *nerve-pentagon*, which surrounds the mouth.

The two radial nerve-bands of the deep nervous systems are thickenings of the lining membrane of a space overlying the radial nerve and underlying the radial ambulacral system. A channel throughout the length of the arm above the radial nerve forms part of a system of channels which are usually regarded as constituting a *blood-vascular system*.

This *radial blood-vessel*, as it is termed, is divided longitudinally by a vertical septum into two lateral halves. Internally it communicates with an *oral ring-vessel* surrounding the mouth and likewise divided into two by a septum. When the dorsal wall of the central disc is dissected away, the remainder of the organs come into view. The rows of ambulacral ossicles appear on this view as ridges, the *ambulacral ridges*, one running along the middle of the ventral surface of each arm to its extremity, and extending inwards to the corresponding angle of the mouth. At the sides of each of these ridges appear the rows of ampullæ. Within the pentagonal actinostome is a space, the *peristome*, covered with a soft integument, and in the centre of this is a circular opening, the true *mouth*, the size of which is capable of being greatly increased or diminished.

The mouth is found to open through a short passage, the *œsophagus*, into a wide sac, the *cardiac division of the stomach* (Fig. 88, *st;* Fig. 89, *card. st*). This is a five-lobed sac, each of the lobes of which is opposite one of the five arms. The walls of the sac are greatly folded, and the whole is capable of being everted through the opening of the mouth, folded over some object desired as food, and then retracted into the interior, the retraction being effected by means of special retractor muscles which arise from the sides of the ambulacral ridges. This cardiac division of the stomach communicates dorsally with a much smaller chamber, the *pyloric division of the stomach*, and this in turn opens into a very short conical *intestine*, which leads directly upwards to open at the small anal aperture. The pyloric division of the stomach is pentagonal, each angle being drawn out to form a pair of large, tree-like appendages, the *pyloric cæca* (Figs. 88 and 89, *pyl. cæc*), which extend to near the extremity of the arm. The walls of the pyloric cæca are glandular: they secrete a digestive fluid, and are therefore to be looked upon as *digestive glands*. It is found by experimenting with this digestive fluid that it has an action on

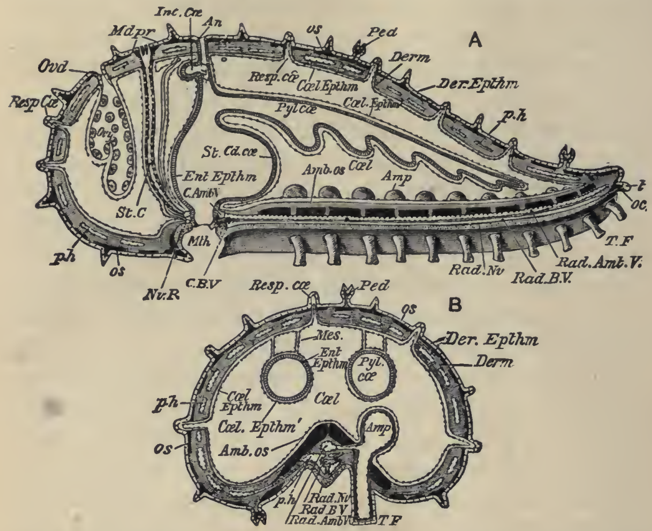
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FIG. 88. — Diagrammatic sections of a starfish. A vertical section passing on the right through a radius, on the left through an inter-radius. The off-side of the ambulacral groove with the tube-feet (*T. F*) and ampullæ (*Amp*) are shown in perspective. B, transverse section through an arm. The ectoderm is coarsely dotted, the nervous system finely dotted, the endoderm radially striated, the mosoderm evenly shaded, the ossicles of the skeleton black, and the cœlomic epithelium represented by a beaded line. *amb. os*, ambulacral ossicles; *amp*, ampullæ; *an*, anus; *C. Amb. V*, circular ambulacral vessel; *C. B. V*, septum of ring blood-vessel; *Cd. cæ*, cardiac cæca; *Cœl*, cœlome; *Cœl. Epithm*, cœlomic epithelium; *Der. Epithm*, deric epithelium; *Derm*, mesoderm; *Ent. Epthm*, enteric epithelium; *Int. cæ*, intestinal cæca; *Mdpr*, madreporite; *Mes*, mesentery; *Mth*, mouth; *Nv. R*, nerve ring; *oc*, eye; *os*, ossicles of body-wall; *ovd*, oviduct; *Ped*, pedicellariæ; *ph*, perihæmal spaces; *pyl. cæc*, pyloric cæca; *Rad. amb. v*, radial ambulacral vessel; *Rad. B. V*, points to septum in the radial blood-vessel; *Rad. Nv*, radial nerve; *Resp. cæ*, dermal branchiæ; *St*, stomach; *St. c*, stone-canal; *t*, tentacle; *T. F*, tube-feet. (From Parker's *Biology*.)

food-matters similar to that exerted by the secretion of the pancreas in the Vertebrata, converting starch into sugar, proteids into peptones, and bringing about the emulsification of fats. From the short intestine are given off inter-radially two hollow appendages, the *intestinal cæca* (Fig. 89, *int. cæc*), each with several short branches of irregular shape.

Running downwards from the madreporite to near the border of the mouth, is an S-shaped cylinder, the *madreporic* or *stone-canal* (Fig. 88, *St. c*). The walls of this canal are supported by a series of calcareous ossicles. The interior of the madreporic canal communicates above with the exterior through the grooves of the madreporite. Below, the canal opens into a wide, five-sided, ring-like canal, the *ring-vessel of the ambulacral system.* From this are given off the five radial ambulacral vessels, passing to the extremities of the arms. From the pentagonal canal are given off also a series of five pairs of appendages, the *Polian vesicles* (Fig. 90, *ap*),

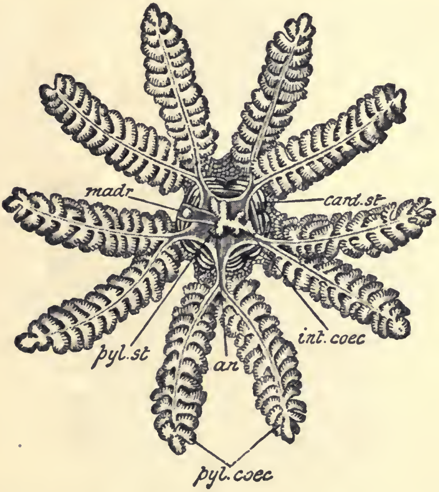

FIG. 89.—**Asterias rubens.** Digestive system. *an*, anus; *card. st*, cardiac division of the stomach; *int. cæc*, intestinal cæca; *madr*, madreporite; *ply. cæc*, pyloric cæca; *pyl. st*, pyloric division of the stomach. (From Leuckart.)

— pear-shaped, thin-walled bladders with long narrow necks, — which are placed inter-radially. On the sides of the neck of each Polian vesicle (except in the inter-radius containing the madreporic canal, where there is one on one side only) project inwards a pair of little rounded glandular bodies, the *racemose vesicles*, or *Tiedemann's vesicles*, the interior of each of which is divided into a number of chambers.

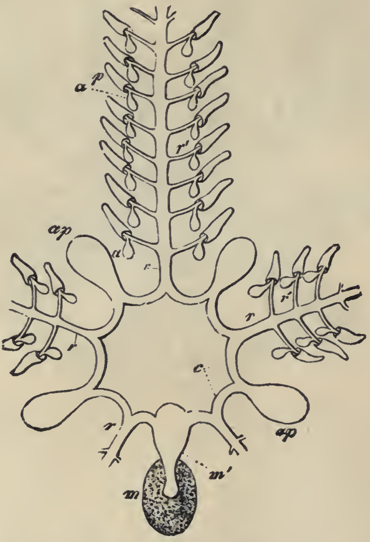

Fig. 90.— Ambulacral system of a starfish. *a*, ampullæ; *ap*, Polian vesicles; *c*, circular canal; *m*, madreporite; *m'*, madreporic canal; *p*, tube-feet; *r*, radial vessels; *r'*, branches to ampullæ. (After Gegenbaur.)

Accompanying the madreporic canal there is an organ, — the *ovoid gland*, — the relationships and function of which have given rise to a considerable amount of difference of opinion. It is a fusiform body, the interior of which is divided up into a number of freely communicating spaces.

The starfish is *unisexual*, each individual possessing either *ovaries* (Fig. 88, *ov*) or *testes*, which appear very similar until they are examined microscopically. They consist of masses of rounded follicles, like bunches of minute grapes, a pair in each inter-radial interval. The ducts, by means of which the ova, or sperms, reach the exterior, open on the dorsal surface (Fig. 88, A, *Ovd*) through a number of perforations on a pair of sieve-like plates, situated inter-radially close to the bases of the arms.

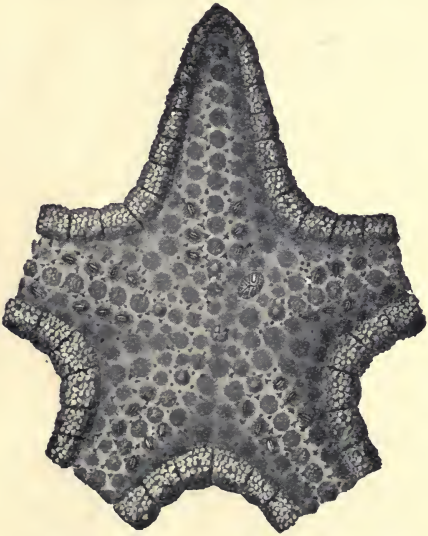

FIG. 91.—**Anthenea.** View of dorsal surface. (After Sladen.)

Other starfishes, while resembling Asterias in most respects, differ from it in a number of less important points. Thus though the number of arms is usually five, in some species it is eight, in others more, and in some of those with more than five arms the number is inconstant. The proportions borne by the arms to the central disc also vary greatly in different kinds, the arms being in many instances relatively longer, in many relatively shorter than Asterias, and in the latter case (Figs. 91 and 92) the central disc is correspondingly increased in extent. In some extreme instances of this modification the starfish assumes the form of a five-angled disc, in which the arms are represented merely by the angles. In all cases the arms are hollow, each containing a prolongation of the body-cavity containing the cæca; and in all the mouth is in the centre of the ventral surface, and narrow ambulacral grooves run out from it in a radiating manner to the extremities of the arms. In some starfishes there are but two rows of tube-feet in each arm. An anus

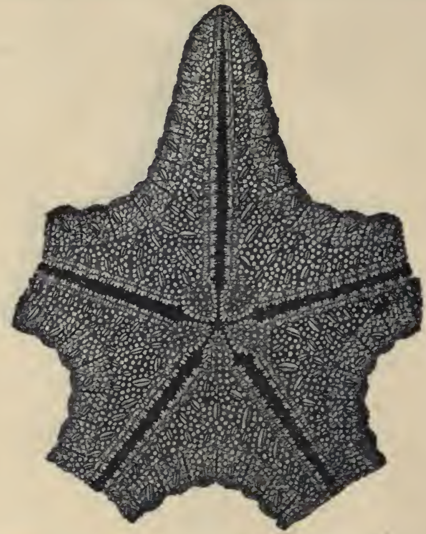

FIG. 92.—**Anthenea.** View of ventral surface. From New Zealand. (After Sladen.)

is sometimes absent; in *Asterias vulgaris* it is minute, almost closed. The spines and pedicellariæ differ in their form and arrangement in different kinds of starfish, as also, though in a less degree, the tube-feet. The starfishes constitute one of the five classes of living Echinodermata, the class **Asteroidea**.

2. THE OPHIUROIDEA

The **Brittle-stars** bear many resemblances to the true starfishes, but have a number of special features of sufficient importance to justify their being regarded as constituting a separate class, which is termed the Ophiuroidea. Like

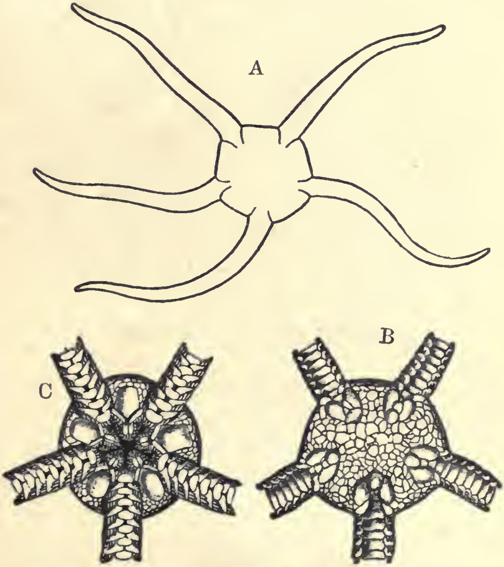

FIG. 93.— **Ophioglypha lacertosa.** A, outline, of the natural size; B, central disc, dorsal view; C, the disc, ventral view showing the mouth and genital fissures. (From Nicholson and Lydekker's *Palæontology*.)

Asterias, the brittle-star (Fig. 93) has a star-shaped body with a central disc and five radiating arms. But the arms, instead of appearing merely as radiating prolongations of the central disc, are sharply marked off from it, and have rather the appearance of appendages. They are solid, long, slender, and tapering, clothed with plate-like ossicles and beset laterally with spines. They are highly flexible, and instead of creeping along slowly like a starfish the brittle-star moves with comparative activity by means of lateral movements of the arms. As in the starfish there are distinct dorsal and ventral surfaces, the former having the mouth in its centre. An anus is absent, and the madreporite is on the ventral surface instead of the dorsal. There are no ambulacral grooves, and the tube-feet project at the side of the arm. The internal structure is similar in most respects to that of the starfish, but the radial prolongations of the body-cavity into the arms are absent, and there are no pyloric cæca. In certain of the Ophiuroidea the arms are branched.

3. THE ECHINOIDEA

The **Sea-urchins** (Class Echinoidea) differ much more widely from the starfishes than the brittle-stars. The body (Fig. 94) is not star-shaped, but globular. At one pole is the mouth, at the other the anus. The body is enclosed in a shell or *corona* (Fig. 95), formed of firmly united plate-like ossicles arranged in rows which run from oral to aboral poles. Supported on these are numbers of long, slender, sharp-pointed, freely movable spines (Fig. 94). Running over the surface from near the oral to near the aboral poles are five bands of tube-feet which are capable of being extended into long slender tubes (Fig. 94). These have sucker-like extremities and, like the tube-feet of the starfish, are the organs of locomotion. A remarkable and characteristic feature of the internal structure is the presence of a complicated apparatus for mastication known as *Aristotle's lantern*, consisting of five jaw-like parts, each bearing a

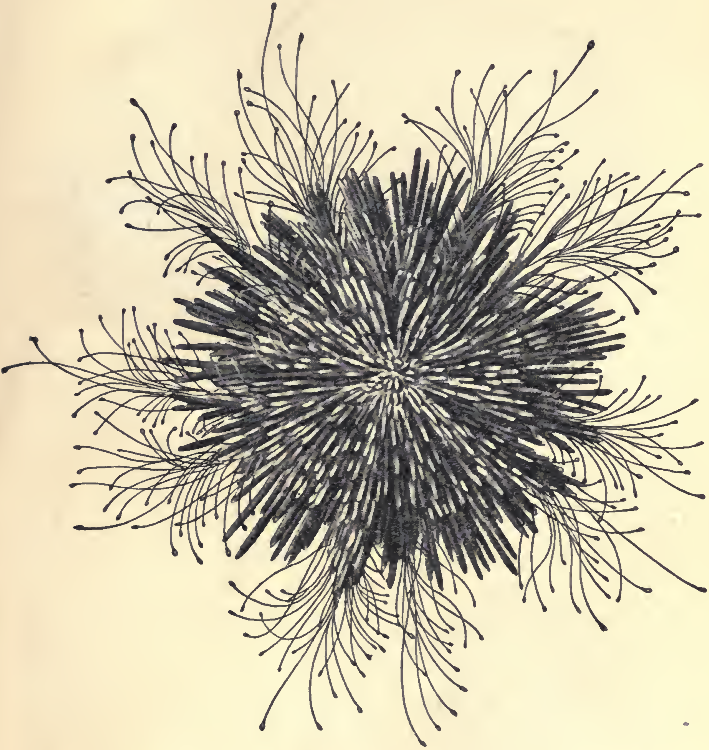

FIG. 94. — **Strongylocentrotus.** Entire animal, with the tube-feet extended beyond the ends of the spines. (From Brehm's *Thierleben.*)

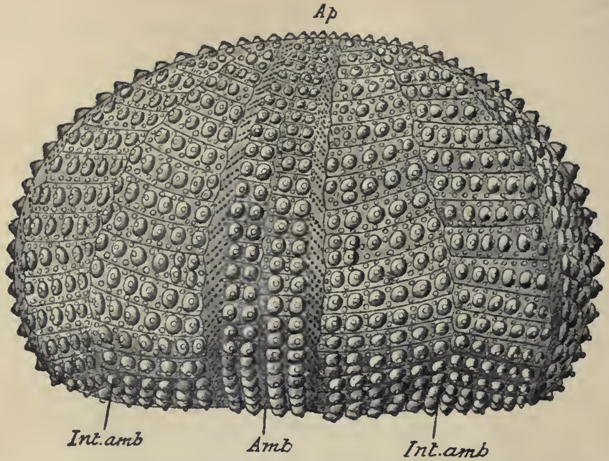

FIG. 95.—Corona of sea-urchin with the spines removed to show the arrangement of the plates, lateral view. *Amb*, ambulacral zone with its perforated plates; *Ap*, apical (aboral) pole; *Int. amb*, inter-ambulacral zones. (From Bronn's *Thierreich.*)

sharp tooth. The points of these five teeth can be seen through the opening of the mouth. The enteric canal has no radiating cœca. The five ducts of the reproductive organs open on five ossicles, the *genital plates* (Fig. 96, *gen*), which with five smaller *ocular* plates (*oc*) each bearing a rudimentary eye, form a complete ring round the space (*peripr*) at the anal pole, in the middle of which is the anus; a madreporite is amalgamated with one of the genital plates.

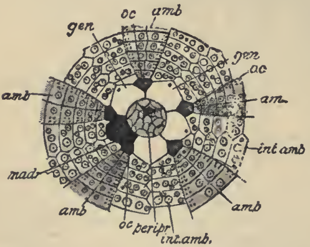

FIG. 96.—Apical system of plates and aboral extremities of zones of the shell of a sea-urchin. *amb*, ambulacral zones; *gen*, genital plates; *int. amb*, inter-ambulacral zones; *madr*, madreporite; *oc*, ocular plates; *peripr*, periproct. (After Leuckart.)

In the *Heart-urchins* (*Spatangus*) the body is heart-shaped instead of globular, and in the *Cake-urchins* (represented by our *Echinarachnius parma*) it is flattened and disc-like. In most respects, however, these *irregular* sea-urchins are very closely allied to the ordinary or regular forms, and with the latter they constitute the third class of Echinodermata, the Echinoidea.

4. THE HOLOTHUROIDEA

Also widely different from the starfishes in the general form of the body are the Holothurians (class **Holothuroidea**). Some of these are known as sea-slugs from their slug-like appearance, others as sea-cucumbers. One is termed the "cotton-spinner" from the cottony filaments which it discharges when irritated or removed from the water. Certain large tropical forms which abound on coral reefs in the Pacific, are used as food and form the object of a fishing industry in connection with which they are known as Bêche-de-mer or trepang (*Holothuria edulis*). Our Floridan trepang is *H. floridana ;* a more northern form is *Pentacta frondosa.* A Holothurian (Fig. 97) is roughly comparable to a sea-urchin the body of which has been drawn out in the direction of the line joining mouth and anus, so that it has assumed a long and slender form. But there is only exceptionally a rigid shell of plates, the body-wall being nearly always flexible and sometimes quite soft and supported by calcareous spicules, and usually one side, habitually directed downwards, is often modified as a ventral surface. A circlet of *tentacles* surrounds the mouth. Five regular zones of *tube-feet* sometimes run from mouth to anus : sometimes those on the dorsal surface may be modified ; sometimes the tube-feet are scattered over the entire surface, in some forms (such as the worm-like *Synapta* and its allies) tube-feet are entirely absent.

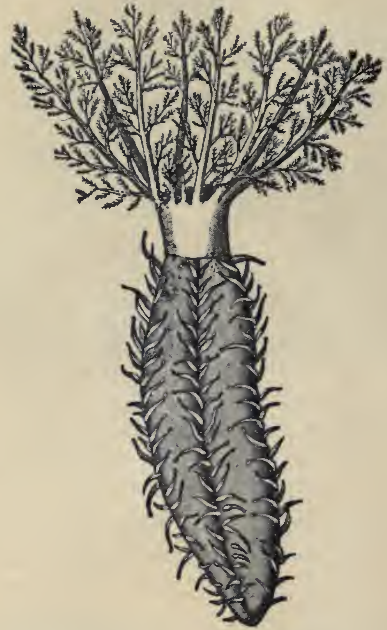

FIG. 97. — **Cucumaria planci.** Entire animal seen from the ventral surface, with the tentacles expanded, and the tube-feet projected outwards. (From Hertwig's *Lehrbuch*, after Ludwig.)

5. THE CRINOIDEA

The **Feather-stars** and their allies constituting the class Crinoidea, bear some superficial resemblances to the star-fishes and brittle-stars, but with some important points of difference. The body of a feather-star (Fig. 98) is star-shaped, with a *central disc* and five *arms* which are bifurcate at their bases. On that surface of the central disc which is directed upwards in the natural position of the animal, is in the centre the *mouth* and on one side the *anus*. On the opposite surface are attached whorls of slender curved cylindrical appendages, the *cirri*, by means of which the animal is able to anchor itself temporarily to a rock or a seaweed. The arms are long, flexible and tapering, shaped

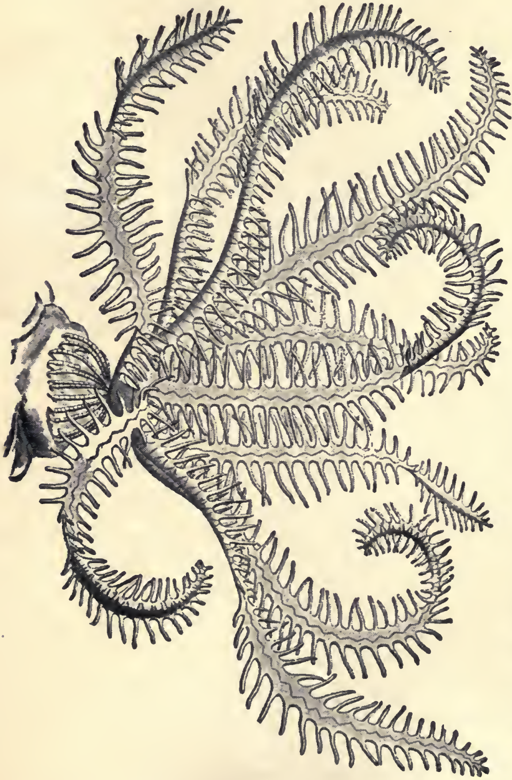

FIG. 98.—**Antedon.** Side view of entire animal. European coasts. (From Leuckart and Nitsche's Diagrams.)

somewhat like a feather, with a main axis and a pair of lateral rows of short slender branches, the *pinnules*. The arms act as the locomotive organs of the animal, their waving movements propelling it slowly through the water. Tube-feet are not developed as such; but are represented by a great number of very minute simple processes, the *tentacles*, which border grooves running along the upper surfaces of the arms and of the pinnules.

Some of the Crinoidea, the **stalked Crinoids** (Fig. 99), chiefly occurring at great depths in the sea are supported on a long slender *stalk* by which they are permanently fixed. In the ordinary feather-stars the larva passes through a stage in which it is attached by means of a stalk like the stalked Crinoids: after a time the stalk becomes absorbed and the young feather-star becomes free.

Our two species of Antedon live in deep water off the New England coast.

A remarkable feature of the Echinodermata is the prevailing *radial arrangement* of their parts, a feature in which they resemble the very much more simply organised Cœlenterata. But underlying this there is to be detected a more obscure arrangement of the body in right and left halves, just as in the *bilateral* animals we have been more recently dealing with. This deeper bilateral symmetry is almost completely disguised by the radial arrangement of most of the parts. In the larva the symmetry is strongly bilateral and it is only by passing through a remarkable metamorphosis in which parts of the larva are sometimes altogether discarded that the radially constructed adult form is developed.

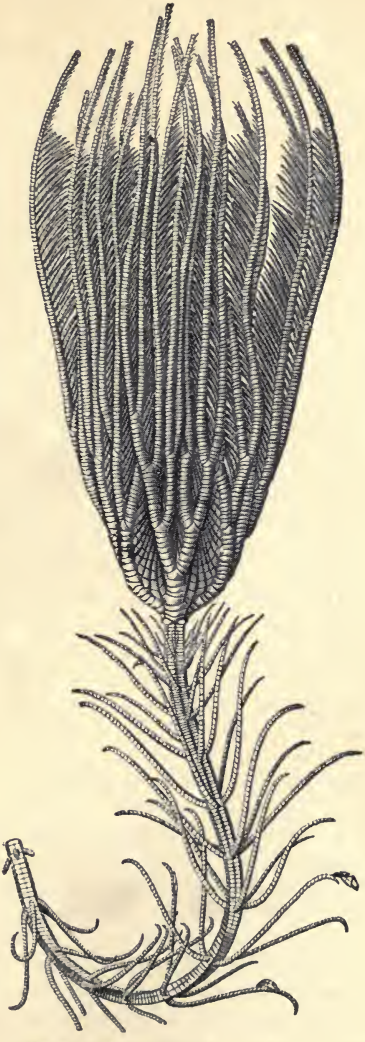

Fig. 99.—**Metacrinus interruptus.** (After P. H. Carpenter.)

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SECTION VIII.—ROTIFERA, POLYZOA AND BRACHIOPODA

1. THE ROTIFERA

A group of Metazoa of microscopic size, the **Rotifera** or Wheel Animalcules, which are of exceedingly common occurrence in fresh water, and are also found, though much less abundantly, in the sea, are readily mistaken on a superficial examination for Infusoria on account not only of their minuteness and the general resemblance in shape of many of them to certain members of that class, but of the presence of cilia as organs of locomotion. A more careful examination, however, shows that these minute creatures are relatively highly organised multicellular animals, and reveals certain general features of resemblance between them and the Trochosphere, which is the characteristic larval form in a phylum to be subsequently dealt with, the Annulata (Section IX.).

The majority of the Rotifera are free-swimming. The cilia, by means of which the swimming movements are effected, are confined to one extremity of the body, the anterior or oral, and are borne on a very characteristic organ termed the *trochal disc* (Fig. 100, *tr. d*). This is in its simplest form a disc with a prominent rim, fringed with strong cilia, and surrounds the oral end. The mode of movement of the cilia is such as to cause the trochal disc to assume the appearance of a rapidly rotating wheel, and it is to this circumstance that the name Rotifera or Wheel-bearer is applied to the group. Sometimes, however, the form of the trochal disc is less simple, the disc with its circlet of cilia becoming divided into lobes, or drawn out into long processes. In some forms ciliated prominences are present within the circlet of cilia, and in others there is a second circlet internal to the first.

The body is usually distinguishable into the *trunk* and the *tail* (*t*). The latter, which is situated at the extremity of the body most remote from the trochal disc, is frequently divided by a series of freely-movable joints into a number of tubular segments like the parts of a telescope. It is provided at its extremity in many forms with a pair of processes which act like the blades of a pair of forceps in enabling the animal to temporarily attach itself. In many forms in which the tail is well-developed locomotion may be effected not only by swimming by the movements of the cilia of the trochal disc, but by creeping or looping

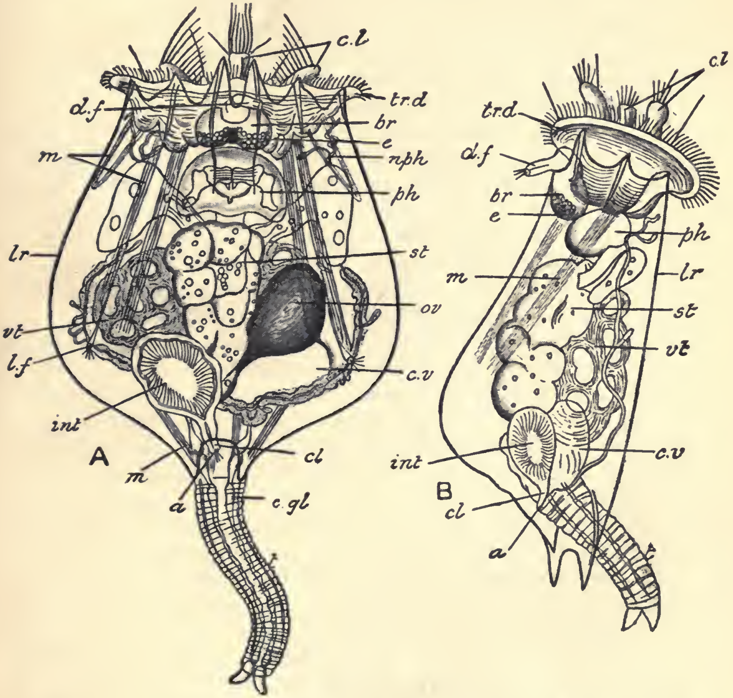

FIG. 100. — **Brachionus rubens.** A, from the dorsal aspect; B, from the right side. *a*, anus; *br*, brain; *d. f*, dorsal feeler; *c. gl*, cement gland; *cl*, cloaca; *c. l*, ciliary lobes; *c. v*, contractile vesicle; *e*, eye-spot; *int*, intestine; *lr*, lorica; *l. f*, lateral feeler; *m*, muscular bands; *nph*, nephridial tubes; *ov*, ovary; *ph*, pharynx; *st*, stomach; *t*, tail; *tr. d*, trochal disc; *vt*, vitellarium. (After Hudson and Gosse.)

movements like those of a leech, the oral end and the extremity of the tail being alternately attached. In Rotifers, which are permanently fixed, attachment is effected through the intermediation of the tail, which is drawn out to form a long narrow stalk. In others the tail is absent, or represented only by a pair of ciliated processes.

The trunk is in some Rotifers enclosed in a glassy cuirass or *lorica* formed of a thickening of the cuticle. One remarkable form — *Pedalion* — has six hollow appendages terminated by feathered setæ: and a few other forms are provided with simple or fringed setæ.

The stalked forms inhabit tubes into which the animal can completely retract itself, the substance of the tube being either a delicate gelatinous material, or composed of pellets of mud, or of the animal's fæces.

The structure of the internal organs is simple. The alimentary canal usually terminates in an anal aperture (*a*). There is a large pharynx (*ph*) containing a masticatory apparatus, the *mastax*, usually consisting of three chitinous pieces, or jaws, of complicated form. The nervous system consists of a single ganglion (*br*), situated towards the oral end; and there are usually one or several very simple eyes (*e*). In close relation to the brain are one or several processes, the *tactile rods* (*d. f*), tipped with non-motile cilia, connected with the ganglion by means of nerves. A pair of longitudinal excretory vessels (*nph*), provided at intervals with short branches terminating in flame-cells, usually open into a contractile vesicle which discharges into the terminal part of the intestine.

The males differ greatly from the females, being nearly always much smaller and degenerate in structure. Three kinds of eggs are produced: large and small *summer eggs* which always develop without fertilisation (*parthenogenesis*) and thick-shelled *winter eggs*, which probably require to be fertilised.

A few Rotifers live in the sea, but the majority are fresh-water forms, occuring in lakes, streams, ponds, and even in puddles the water of which is rendered foul and opaque by mud and sewage. Frequently the water in which they live is dried up, and the thick-shelled winter eggs may then be widely dispersed by wind. It is even stated that the adult animals may survive prolonged desiccation and resume active life when again placed in water. Many forms cling to the bodies of higher animals in order to obtain a share of their food, thus leading a sort of commensal existence. Others go a step further and become true external or internal parasites.

2. THE POLYZOA

The **Polyzoa** are an extensive class of animals for the most part marine, which, from the general form that they assume, are readily mistaken for hydroid zoophytes (Hydrozoa, p. 91). They occur as fixed colonies, the form of which varies greatly, supported by an exoskeleton which is sometimes gelatinous, sometimes chitinoid, sometimes calcareous. They either encrust rocks, forming little patches, or they grow up with a plant-like habit. Most usually the colony is a branching, plant-like structure, though it may assume other forms. The whole consists essentially of a number of minute chambers, or *zoœcia*, as they are termed, each formed by the exoskeleton of one of the zooids. Each zoœcium (Figs. 101 and 102) has an aperture, sometimes capable of being closed by a lid or *operculum*, through which the oral extremity of the zooid is capable of being protruded. At this protrusible oral end of the zooid is a circular or horseshoe-shaped ridge or *lophophore* bearing a number of simple, slender, ciliated tentacles (*tent*). In many Polyzoa the colony bears a series of remarkable appendages, the *avicularia*, of the nature of modified zooids. A typical avicularium (Fig. 101, *avic*) has very much the appearance of a bird's head supported on a very short stalk, with a movable part representing the lower jaw, which becomes separated from or approximated to the part representing the upper jaw by movements which closely resemble the movements of opening and closing of the bird's mouth. These are probably defensive organs. The mouth (*mo*) is a large aperture in the middle of the oral extremity within the lophophore: the anus is situated near it, but outside the lophophore. The digestive canal is a U-shaped tube, divided into pharynx (*ph*), stomach (*stom*), and intestine (*int*), suspended within a wide body-cavity. There is no vascular system, and the central part of the nervous system consists of a single ganglion (Fig. 102, *gang*), placed between mouth and anus. The sexes are united, and there is a free-swimming cilia larva.

Probably allied to the ordinary Polyzoa thus briefly characterised, and usually assigned to that class, are three genera, *Pedicellina* (Fig. 103), *Loxosoma* and *Urnatella*, the first two colonial, the third solitary, which, among other special features, have the anus situated within the circlet of the tentacles. These are known as the **Endoprocta**, as

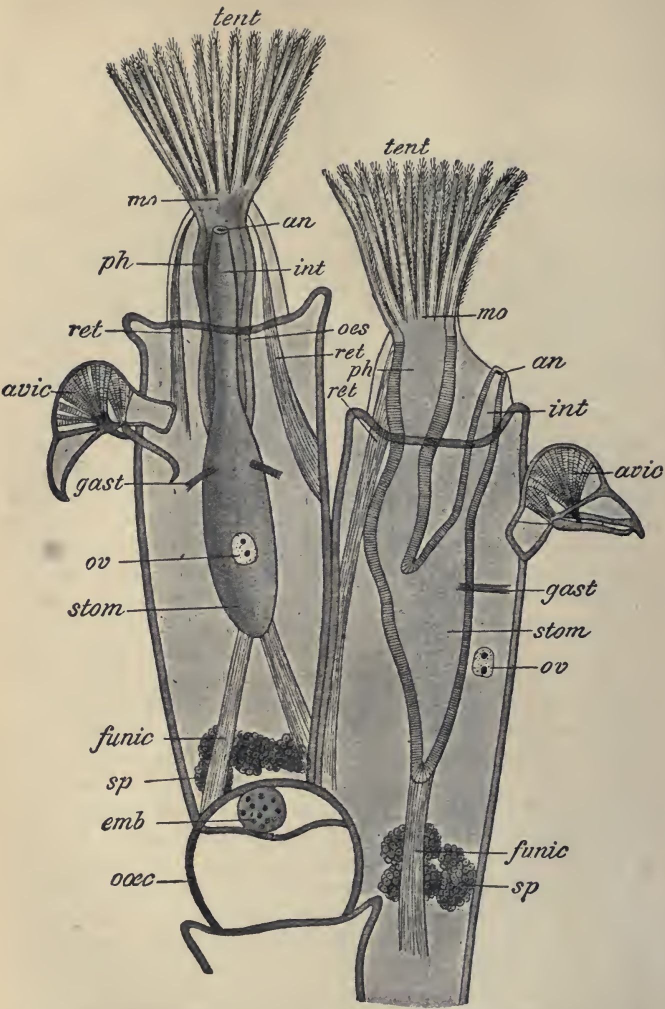
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FIG. 101. — **Bugula avicularia.** Two zooids, magnified. *an*, anus; *avic*, avicularia; *emb*, embryo enclosed in the oœcium; *funic*, funiculus; *gast*, muscular bands passing from the stomach to the body-wall; *int*, intestine; *mo*, mouth; *oœc*, oœcium; *œs*, œsophagus; *ov*, ovary; *ph*, pharynx; *ret*, parieto-vaginal muscles; *sp*, spermatidia: *stom*, stomach.

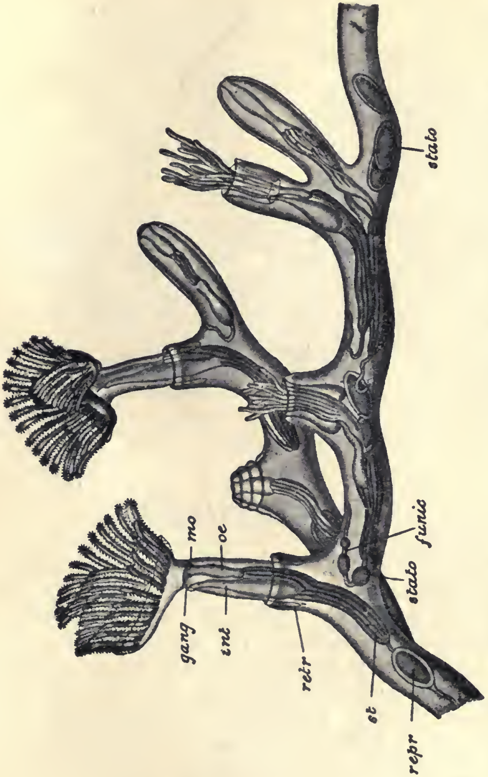
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FIG. 102. —**Plumatella.** Portion of a colony magnified. *gang*, ganglion; *int*, intestine; *mo*, mouth; *œ*, œsophagus; *repr*, reproductive gland; *retr*, retractor muscle; *st*, stomach; *stato*, statoblasts. (After Allman.)

distinguished from the **Ectoprocta** or ordinary Polyzoa, in which the anus, as we have seen, is external to the lophophore and tentacles.

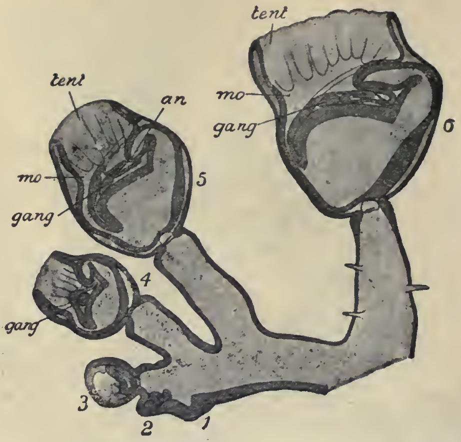

FIG. 103. — **Pedicellina.** Showing successive stages (numbered *1* to *6*) in the development of zooids by budding. *an*, anus; *gang*, ganglion; *mo*, mouth; *tent*, tentacles (retracted). (After Hatschek.)

3. THE BRACHIOPODA

The **Brachiopoda**, or Lamp-shells, are a group of marine animals which present certain important features of resemblance to the Polyzoa, and on that account are placed with them in a special phylum to which the name **Molluscoida** is applied. The Brachiopoda are solitary, never giving rise to colonies like those of the Polyzoa, and one of their most striking characteristics is the possession of a calcareous shell which bears a remarkable resemblance to that of the members of a widely different group, the Pelecypoda of the phylum Mollusca, the group to which the mussels, oysters, and clams belong. The shell (Fig. 104) consists of two pieces or valves, one dorsal (*d. v*), the other ventral (*v. v*), and the animal is attached by a horny stalk or peduncle (Fig. 105, *pd*) which passes through an aperture (Fig. 104 *f*) in a process, the *beak* (*b*), of the ventral valve. In the natural state the peduncle is attached to a rock or other support, and the animal lies with the ventral valve uppermost and the two valves gaping slightly. The end of the valve at which the peduncle is situated is regarded as posterior, the opposite end as anterior. The two valves articulate together by a more or less distinct hinge situated at the posterior end, and the movements of both opening and closing of the shell about this hinge are effected by means of muscles passing internally between the valves.

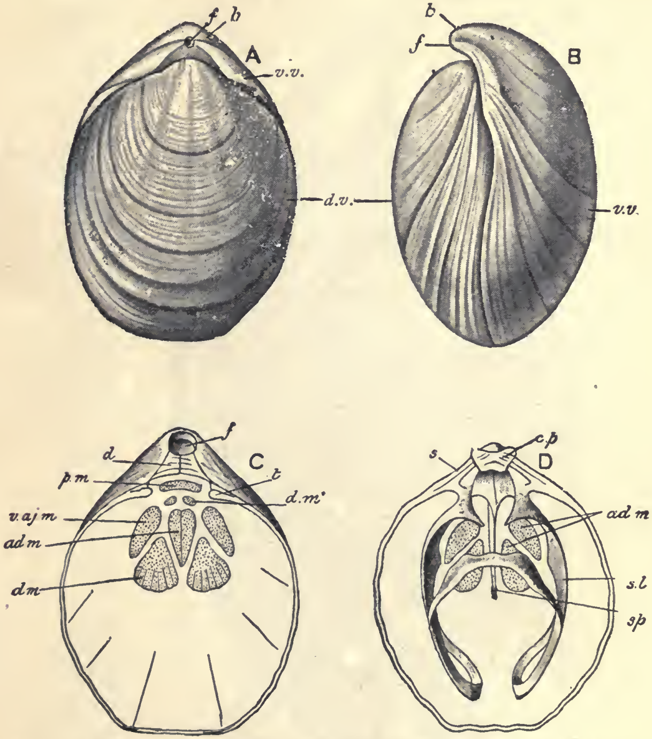

FIG. 104.—**Magellania flavescens.** A, the entire shell from the dorsal aspect; B, from the left side; C, interior of ventral valve; D, of dorsal valve; *ad. m*, adductor impressions; *b*, beak; *c. p*, cardinal process; *d*, deltidium: *d. m*, divaricator impressions; *d. v*, dorsal valve; *f*, foramen; *p. m*, protractor impressions; *s*, tooth-socket; *s. l*, shelly loop; *sp*, septum; *t*, tooth; *v. v*, ventral valve. Australian seas. (After Davidson.)

The body of the animal occupies a relatively small part of the space contained in the interior of the shell and lies toward the posterior end.

The rest of the space is lined by a pair of folds of the body-wall, the *mantle-folds* (Fig. 105), *d. m*, *v. m*), the edges of which are beset with minute setæ (*s*). In the space (*mantle-cavity*) lined by these mantle-folds lies a *lophophore* (*lph*), usually of complicated form, fringed with long ciliated tentacles, and supported in many cases by a delicate, sometimes simple, sometimes complicated, shelly process of the dorsal valve, the *shelly loop* (Fig. 104, *s. l.*). The mouth (Fig. 105, *mth*),

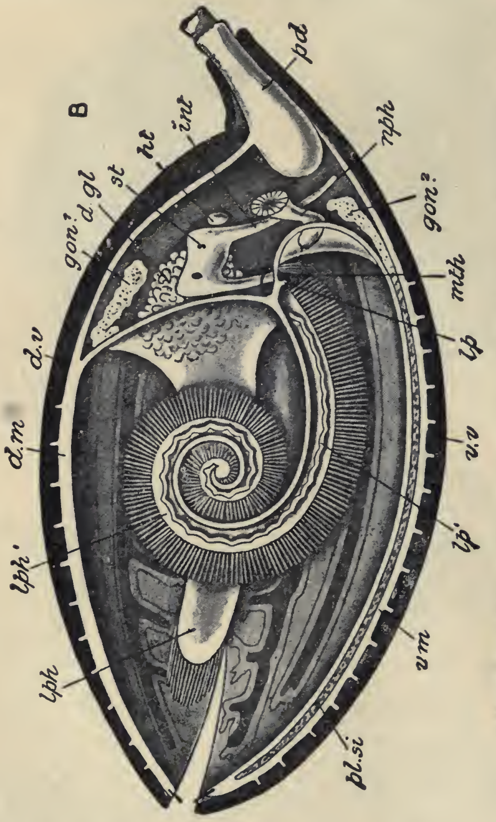

FIG. 105.—**Magellania lenticularis.** Sagital section of the entire animal. *d. gl*, digestive gland; *d. m*, dorsal mantle-lobe; *d. v*, dorsal valve of shell; gon^1, gon^2, gonads; *ht*, heart; *int*, intestine; *lp*, lp^1, lip; *lph*, lophophore; lph^1, its coiled process; *mth*, mouth; *nph*, nephridium; *pd*, peduncle; *pl. si*, pallial sinuses; *s*, setæ; *v. m*, ventral lobe of mantle; *v. v*, ventral valve of shell. New Zealand coast.

situated in the middle of the anterior body-wall within the lophophore, leads into a V-shaped digestive canal (*st. int*), which may or may not terminate in an anal aperture. A heart is present in the form of a contractile sac, and there is a feebly developed vascular system. The central part of the nervous system is in the form of a nerve ring, with ganglia, which surrounds the œsophagus. There is a pair of large funnel-shaped nephridia (*nph*) which act also as reproductive ducts, leading from the cœlome to the mantle-cavity. The sexes are sometimes separate, sometimes united.

The Brachiopoda are all marine. They are widely distributed geographically, and live at various depths, from between tide-marks to twenty-nine hundred fathoms. At the present day the class includes only about twenty genera and a hundred species, but in former geological periods the Brachiopoda were much more numerous, 106 genera being known from the palaeozoic rocks, there being nearly two thousand fossil species.

Lingula pyramidata occurs in sand at or near low water from Chesapeake Bay to Florida. Our common northern species, *Terebratulina septentrionalis*, lives north of Cape Cod, attached to rocks in from ten to fifty fathoms.

SECTION IX.—PHYLUM ANNULATA

An earthworm, a lobworm, and a leech, when compared with one another, will at once be seen to possess certain features in common. Each is bilaterally symmetrical, long and relatively narrow in shape, is transversely ringed or jointed, and has a soft integument; each has a mouth opening towards the anterior end and a smaller anal aperture towards the posterior end. The earthworm and the lobworm, moreover, resemble one another in possessing a number of bristles, extremely short in the former, disposed regularly in groups along the rings of the body. The ringed or annulate appearance is found, on a closer inspection, to be due to the elongated body being made up of a row of similar parts, the *segments* or *metameres*, which are remarkably uniform throughout the length of the body, not only in external appearance, but in internal structure. A general correspondence is found to exist in the disposition of the internal organs of all the three, and the conclusion is arrived at that they are all members of one phylum. The phylum in question, the **Annulata**, comprises the earthworms, the class of the marine segmented worms or Annelids to which the lobworm belongs, the leeches and certain other groups.

1. THE CHÆTOPODA

The rows of bristles above referred to as disposed along the segments of the body in the earthworm and the lobworm constitute one of the distinguishing features of the class Chætopoda or "bristle-footed" worms of the phylum Annulata. Of these a good and common example is **Nereis** — a marine Annelid of common occurrence under stones and among shells and seaweed on the sea-shore in all parts of the world. The following account of the European *Nereis dumerilii* will apply, with slight differences, to our common *Nereis virens*.

In shape (Figs. 106–109) the body, which may be about 7 or 8 centimetres in length, is long and narrow, approximately cylindrical, somewhat narrower towards the posterior end. A very distinct *head*, bearing eyes and tentacles, is recognisable at the anterior end; the rest is divided by a series of ring-like narrow grooves into a corresponding series of *segments* or *metameres*, which are about eighty in number altogether; and each of these bears laterally a pair of movable muscular processes called the *parapodia*, provided with bundles of bristles or *setæ*. The head (Fig. 109) consists of two parts, the *prostomium* (*præst*) and the *peristomium* (*perist*). The former bears on its dorsal surface four large rounded eyes, in front a pair of short cylindrical *tentacles* (*tent*), and further back a pair of somewhat longer stout appendages or *palpi* (*palp*). The *peristomium*, which presents some resemblance to the segments of the body, though wanting the parapodia, bears laterally four pairs of long slender cylindrical tentacles (*perist*, *tent*):

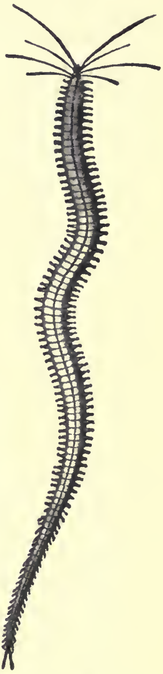

FIG. 106. — **Nereis dumerilii.** Natural size. (After Claparède.)

on its ventral aspect is a transversely elongated aperture, the aperture of the mouth. The segments of the body differ little in external characters from one another throughout the length of the worm. Each bears laterally a pair of parapodia which in the living animal are usually in active movement, aiding in creeping, or acting as a series of oars for propelling it through the water. When one of the parapodia (Fig. 107) is examined more attentively it is found to be biramous, or to consist of two distinct divisions — a dorsal, which is termed the *notopodium* (*noto*), and a ventral, which is termed the *neuropodium* (*neuro*). Each of these is further subdivided into several lobes, and each bears a bundle of setæ. Each of the bundles of setæ is lodged in a sac formed by invagination of the epidermis, the *setigerous sac*, and is capable of being protruded or retracted and turned in various directions by bundles of muscular fibres in the interior of the parapodium. In each bundle there is, in addition to the ordinary setæ, a stouter, straight, dark-coloured seta (*ac*), the pointed apex of which projects only a short distance on the surface; this is termed the *aciculum*. The ordinary setæ (Fig. 108) are exceedingly fine, but

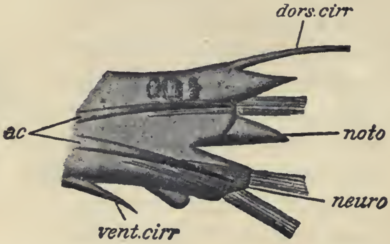

FIG. 107.—**Nereis dumerilii.** A single parapodium magnified. *ac*, aciculum; *dors. cirr*, dorsal cirrus; *neuro*, neuropodium; *noto*, notopodium; *vent. cirr*, ventral cirrus. (After Claparède.)

stiffish, chitinous rods, of which two principal kinds are recognisable; both have a terminal *blade* articulating with the main shaft of the seta by a distinct joint. On the dorsal side of the parapodium is a short cylindrical, tentacle-like appendage, the *dorsal cirrus* (Fig. 107, *dors. cirr*), and a similar, somewhat shorter, appendage, the *ventral cirrus* (*vent. cirr*), is situated on its ventral side. The last segment of the body, the *anal segment*, bears posteriorly a small rounded aperture, the *anus;* this segment is devoid of parapodia, but bears a pair of appendages, the *anal cirri*, similar in character to the cirri of the ordinary segments, but considerably longer.

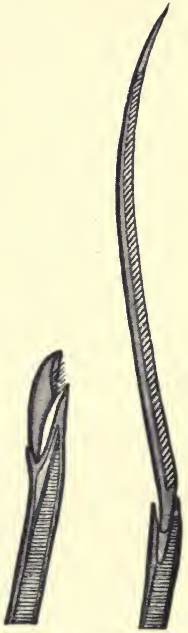

FIG. 108. – **Nereis dumerilii.** Setæ highly magnified. (After Claparède.)

On the ventral surface, near the bases of the parapodia, there is in each segment a pair of very fine apertures, the openings of the nephridia.

The *enteric canal* is a straight tube running throughout the length of the body from the mouth to the anus. Between the outer surface of this tube and the inner surface of the wall of the body is a considerable space — the *cœlom*, *body cavity*, or *perivisceral cavity* — filled with a fluid, the *cœlomic fluid.* The space is divided by a series of transverse partitions or *septa* passing inwards from the body-wall to the walls of the alimentary canal opposite the grooves between the segments, and thus dividing the cœlom into a series of chambers, each of which corresponds to one of the seg-

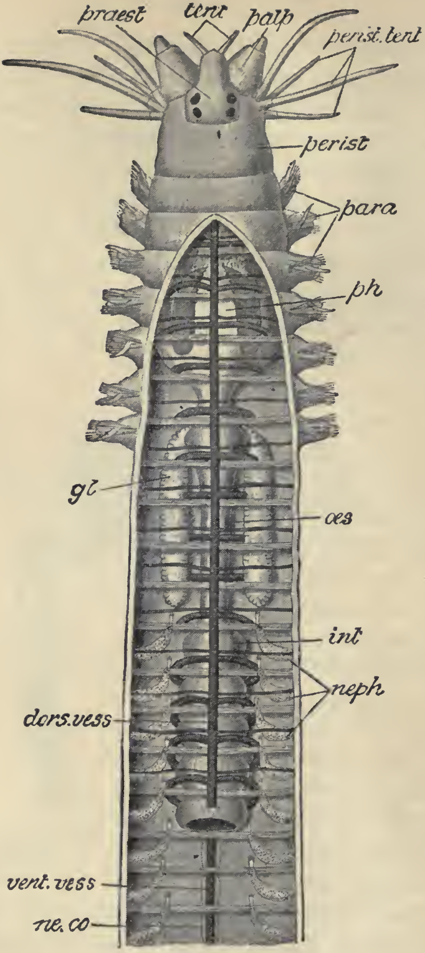
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FIG. 109.—**Nereis dumerilii.** Semi-diagrammatic view of the anterior portion of the body, with the dorsal body-wall removed, so as to show the alimentary canal, the septa, the blood-vessels and the nephridia; a portion of the intestine removed so as to show the ventral blood-vessel and nerve-cord which lie below. *dors. vess*, dorsal vessel; *gl*, œsophageal glands; *int*, beginning of intestine; *ne. co*, nerve cord; *neph.* nephridia; *œs*, œsophagus; *palp*, palp; *para*, parapodia; *perist*, peristome; *perist. tent*, peristomial tentacles; *ph*, pharynx with its jaws; *præst*, prostomium; *vent. vess*, ventral vessel.

ments. These partitions are not complete, spaces being left around the alimentary canal and elsewhere, through which neighbouring chambers communicate.

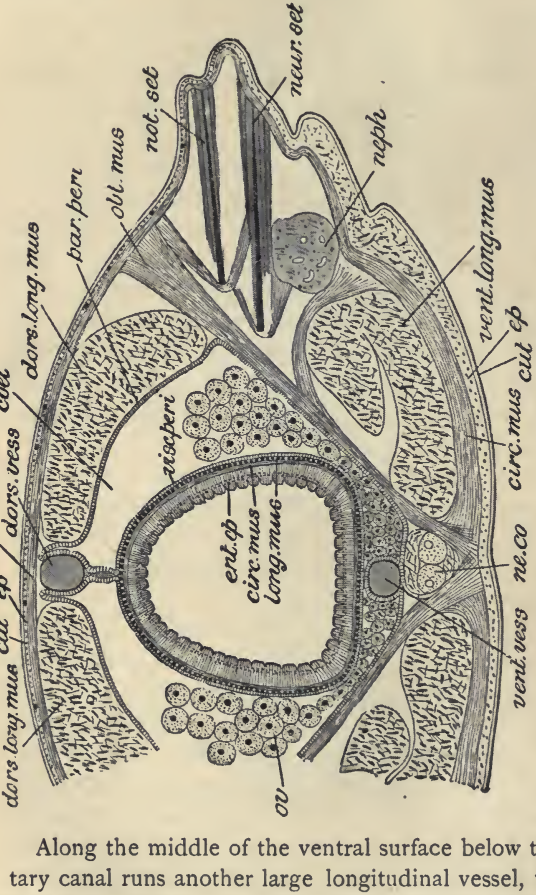
The mouth leads into a wide cavity, the *buccal cavity* continued back into a *pharynx* (Fig. 109, *ph*). In the pharynx are a number of very small dark brown chitinous *denticles*, which are very regularly arranged. The posterior part of the pharynx has very thick walls composed of bundles of muscular fibres, which are concerned in the movement of a pair of laterally placed chitinous *jaws*.

Behind the pharynx the alimentary canal narrows considerably to form a tube, the *œsophagus* (*œs*), which runs through about five segments to open into the intestine.

The anterior part of the alimentary canal is capable of being everted as a *proboscis* until the jaws are thrust forth and thus rendered capable of being brought to bear on some small living animal, or fragment of animal matter, to be seized and swallowed as food.

Into the œsophagus open a pair of large unbranched glandular pouches, or *cæca* (*gl*), which probably are of the nature of digestive glands. The *intestine* (*int*) is a straight tube of nearly uniform character throughout, regularly constricted between the segments.

Nereis has a well-developed system of *vessels* filled with blood of a bright red colour. A main *dorsal vessel* (Figs. 109 and 110, *dors. vess*) runs from one end of the body to the other above the alimentary canal, and is visible in places through the body-wall in the living animal. It, as well as the majority of the vessels, undergoes contractions which are of a *peristaltic* character — waves of contraction passing along the wall of the vessel so as to cause the movement of the contained blood. These peristaltic contractions are more powerful in the case of the dorsal vessel than in that of any of the others, and run with great regularity from behind forwards, so as to drive a current of blood in that direction.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obl.mus
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vent.long.mus
ep
cut
circ.mus
ne.co
vent.vess
visc.peri
ent.ep
circ.mus
long.mus
ov

FIG. 110.—**Nereis dumerilii.** Semi-diagrammatic transverse section of the middle region of the body. *circ. mus* (external), circular layer of muscle of body-wall; *circ. mus* (internal), circular layer of muscle of wall of enteric canal; *cœl*, cœlom; *cut*, cuticle; *dors. long. mus*, dorsal longitudinal muscles of body-wall; *dors. vess*, dorsal vessel; *ent. ep*, enteric epithelium; *ep*, epidermis; *long. mus*, longitudinal muscle of wall of enteric canal; *ne. co*, nerve cord; *neph*, nephridium; *neur. set*, neuropodial setæ and aciculum with their muscles; *not. set*, notopodial setæ and aciculum; *obl. mus*, oblique muscle; *ov*, ovary; *par. peri*, parietal layer of cœlomic epithelium; *vent. long. mus*, ventral longitudinal muscle; *vent. vess*, ventral vessel; *visc. peri*, visceral layer of peritoneal epithelium.

Along the middle of the ventral surface below the alimentary canal runs another large longitudinal vessel, the *ventral vessel* (*vent. vess*), in which the current of blood takes a direction from before backwards. Connecting the dorsal and ventral vessels, there are in each segment two pairs of loop-like transverse vessels which give off branches to the parapodia, the alimentary canal, and neighbouring parts.

There is a well-developed *nervous system* (Fig. 112) which is bilateral and metameric in its arrangement, like the other systems of organs. Situated in the prostomium is a large bilobed mass of nerve-matter containing numerous nerve-cells, the *cerebral ganglion* or *brain* (*c*). This gives off *tentacular* nerves to the tentacles and palpi, and two pairs of short thick *optic* nerves to the eyes. Behind, two thick nerve strands, the *œsophageal connectives* (*d*), curve round the mouth in the peristomium to meet on the ventral aspect behind the mouth and below the pharynx. The œsophageal connectives, with the cerebral ganglion, thus form a ring around the anterior part of the enteric canal. Running backwards from the point of union of the œsophageal connectives, along the entire length of the body of the worm, on the ventral aspect, is a thick cord of nerve-matter, the *ventral nerve-cord* (*h*). In each segment this cord presents a little dilatation from which nerves are given off to the various parts of the segment: and each of these enlargements is really double, consisting of a pair of closely-united ganglia. The intermediate parts of the cord, between successive pairs of ganglia, are also double, consisting of a pair of longitudinal *connectives* enclosed in a common sheath. Given off behind from the cerebral ganglion is a system of fine nerves with occasional small ganglia, the *stomatogastric* or *visceral system*, distributed to the anterior part of the alimentary canal.

The tentacles and palpi, as well as the cirri, are probably organs of the sense of touch. The only other sense-organs are the four eyes, situated on the prostomium. The eye

(Fig. 111) consists of a darkly pigmented cup, the *retina* (*re*), with a small rounded aperture, the *pupil*, and enclosing a mass of gelatinous matter, the *lens* (*l*).

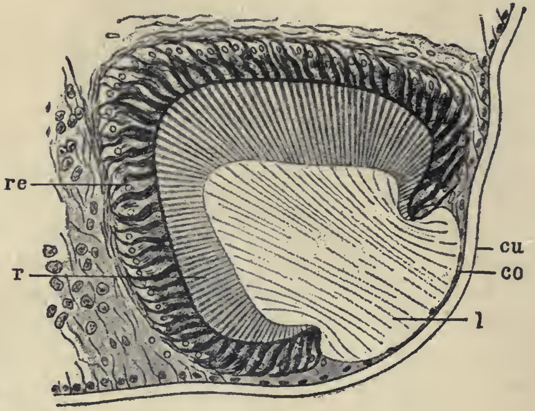

FIG. 111.—Section through an eye of **Nereis**. *co*, cornea; *cu*, cuticle; *l*, lens; *r*, layer of rods; *re*, retina. (After Andrews.)

The organs which are supposed to perform the function of excretion are a series of metamerically arranged pairs of internally ciliated tubes, the *segmental organs* or *nephridia* (Figs. 109 and 110, *neph*) occurring in all the segments of the body. Each of these has an external opening or *nephridiopore*, a fine circular pore capable of being widened or contracted, situated on the ventral surface not far from the base of the ventral cirrus, and opening internally into the cœlom through a ciliated bell or funnel, the *nephrostome*, projecting through the mesentery into the cavity of the segment next in front of that in which the body of the organ lies.

Nereis is unisexual. The sexual elements, ova or sperms, are formed from temporary masses of cells (*ovaries* or *testes*), which are developed towards the breeding season by a proliferation of the cells of the membrane (*peritoneum*) lining the cœlom and the structures it contains.

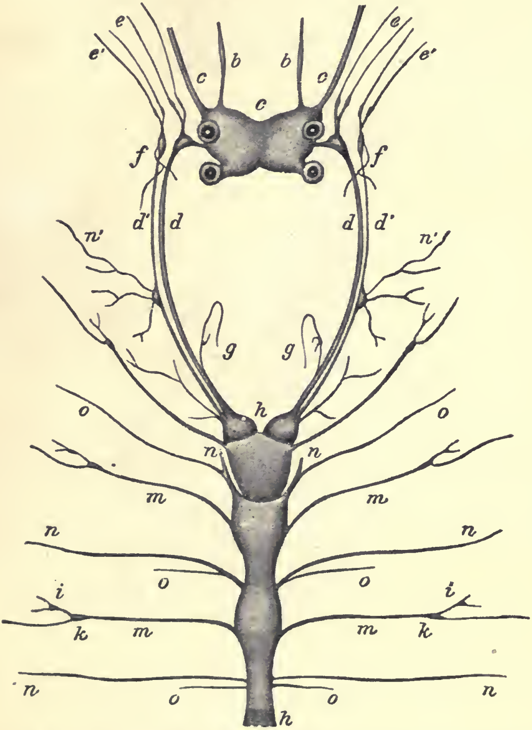

FIG. 112.—**Nereis.** Anterior portion of nervous system, comprising the brain, the œsophageal connectives, and the anterior part of the ventral nerve-cord. .(After Quatrefages.)

Ova and sperms, when fully ripe, are discharged, reaching the exterior, in the case of the sperms probably through the nephridia; in the case of the ova, which are much too large to pass out in this way, probably through apertures temporarily formed by rupture of the body-wall; and impregnation takes place by contact between the two sets of elements while floating freely in the sea-water.

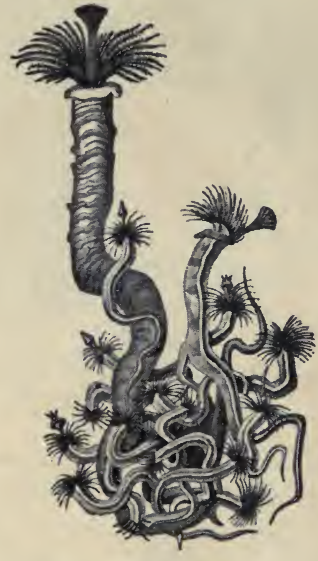

FIG. 113.—**Serpulæ** with their tubes. (After Quatrefages.)

Other annelides which may be collected along with Nereis on the sea-shore will be found to resemble it in the segmented character of the body, and the presence of parapodia with setæ, but to differ from it in the general shape, the number of the segments, the form of the parapodia, and the arrangement and shape of the setæ, the form of the head with its eyes and tentacles, and other points. Many possess *branchiæ*, organs which are absent as such in Nereis, in the form of simple or branched vascular processes arranged in pairs on the dorsal side of the parapodia, throughout the whole or a part of the length of the body, or (Fig. 113) confined to the head-end. All such marine worms belong to the sub-class **Polychæta** of the **Chætopoda.** Though many of them move about freely like Nereis, others live permanently in tubes of a membranous or shelly material. The tube-inhabiting Polychæta (Fig. 113) usually present marked modifications of form in accordance with their mode of life. The branchiæ when present are usually confined to the head-end, so that they can easily be thrust out through the opening of the tube, and the body is fre-

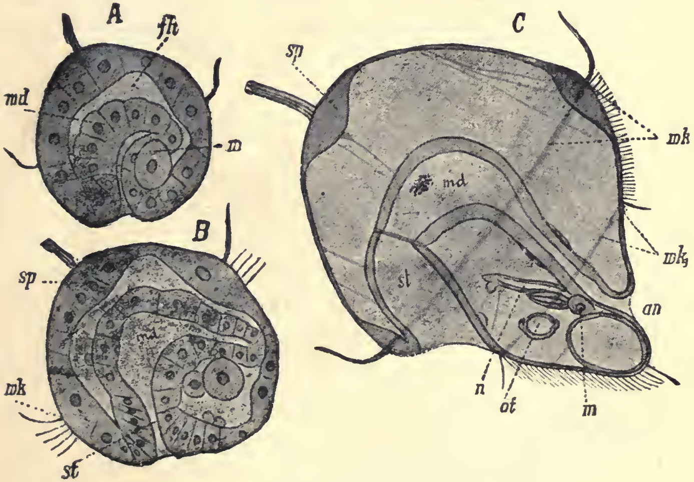

Fig. 114.—*A*, *B*, *C*, three stages in the development of the Trochosphere of **Eupomatus**, from the side. *an*, anus; *fh*, blastocœle; *m*, polar cells of the mesoderm; *md*, mid-gut; *n*, larval head-nephridium; *ot*, otolith; *sp*, neural plate; *st*, stomodæum; *wk*, preoral ciliated ring; *wk*$_1$, post-oral ciliated ring. (From Lang's *Comparative Anatomy*.)

quently divisible into regions owing to more or less marked differences in the development of the parapodia and other points, between the anterior part which may be thrust out of the tube and the posterior parts which habitually remain enclosed in it. All the Polychæta, with one or two exceptions, have the sexes separate, and have a free-swimming

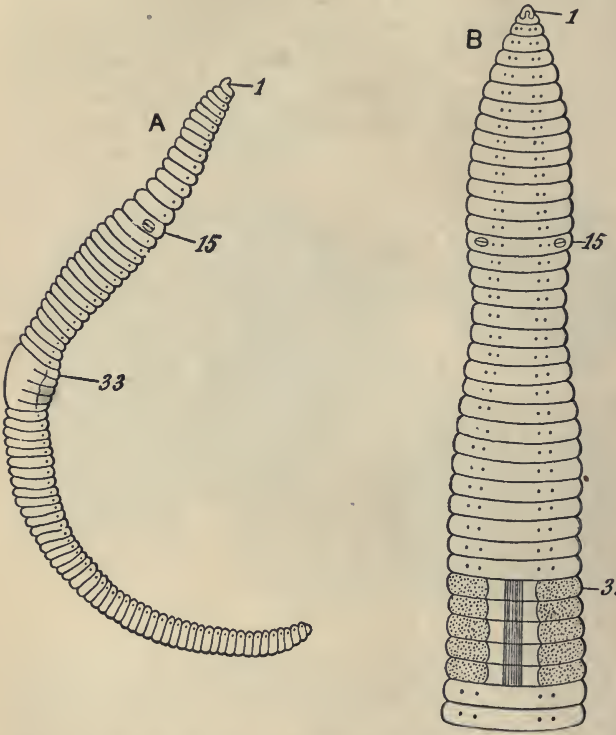

FIG. 115.—**Lumbricus agricola.** A, entire specimen, lateral view; B, ventral view of anterior portion of the body, magnified. *1*, *15*, *33*, first, fifteenth, and thirty-third segments. The black dots represent the setæ. (After Vogt and Jung.)

pelagic larva, the *Trochosphere* (Fig. 114), provided with one or several circlets of cilia.

When a common earthworm is compared with Nereis, certain resemblances are at once discernible. The earthworm (Fig. 115) has the same elongated cylindrical body, divided by ring-like grooves into a large number of segments or metameres. But the well-developed head-region is absent, as are the eyes, palpi, and tentacles, and the parapoda are not present, nor the dorsal and ventral cirri. Setæ, however, are present (Fig. 116), though so short as to be distinguishable with difficulty; two double rows run along each side of the ventral surface, so that there are altogether eight of these short setæ on each segment. A thickened zone—the saddle or *clitellum*—is to be observed extending over five segments, in front of the middle of the body. In internal structure there is a considerable resemblance; but the reproductive organs are hermaphroditic in arrangement and more complex in structure than in Nereis. There are two special male ducts or vasa deferentia, opening on the ventral surface of the fifteenth segment, and female ducts or oviducts opening on the fourteenth.

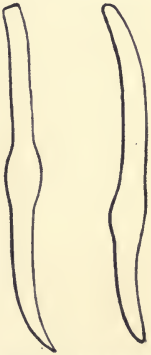

Fig. 116. — **Lumbricus,** setæ, highly magnified.

The fertilised ova of the earthworm are enclosed, together with a quantity of an albuminous fluid in a *cocoon*, the wall of which is formed of a viscid secretion from the glands of the clitellum, hardened and toughened by exposure to the air. The cocoon is deposited in the earth, and the embryos develop into complete, though minute, worms before they make their escape. At a certain stage the embryos are nourished by swallowing the albuminous fluid contained in the cocoon.

The earthworms, together with a number of allied fresh-water forms, constitute the sub-class **Oligochæta** of the Chætopoda. As a group they are distinguished from the Polychæta by the sexes being united in the same individual, with the ovaries and testes compact and few in number, by the absence of parapodia and cirri, the non-development of a distinct head-region, and the absence of a free larval stage.

Very few Chætopoda are true parasites, but a considerable number are to be set down as commensals, habitually associating with another animal for the sake of food and shelter. The earthworms burrow in soil containing decaying vegetable matter, passing the mould through their intestine and subsequently throwing it off in the shape of "castings" on the surface. They also feed on decaying leaves, and sometimes on animal substances. Some of the fresh-water Oligochæta manufacture tubes of mud held together by a tenacious secretion from glands in the integument. Some of the Polychæta move about freely or burrow in sand, or even in rock or in the shells of molluscs; some occupy temporary tubes; others inhabit permanent tubes sometimes of parchment-like consistency, sometimes hardened by deposition of grains of sand, small fragments of shell or other foreign bodies, sometimes of dense, shelly, calcareous material. These tubes are usually firmly fixed to a rock or a seaweed or other foreign body. While the free-living Polychæta are carnivorous in their diet, those that inhabit permanent tubes are vegetable feeders.

A few Polychæta are pelagic. The majority live among sand, mud, rock, or seaweed in shallow water, or actually between high- and low-water limits; but they also occur at all depths in the ocean.

2. THE HIRUDINEA

A good example of the Hirudinea is the medicinal leech (**Hirudo**), various species of which are to be found in ponds, swamps, and slowly flowing streams in various parts of the world.

It is a vermiform animal, some 6–10 cm. (2–3 inches) in length, but is capable of contracting and elongating itself so as to produce great alterations in form and proportion. It moves by "looping" movements, and is also a good swimmer. The body (Fig. 117) is depressed or flattened dorso-ventrally, the dorsal surface convex, the ventral flattened. The anterior end presents a ventrally directed, cup-like hollow, the *anterior sucker* (*a. s*), in the middle of which is a small aperture, the *mouth* (*mth*). The hinder end bears a disc-like *posterior sucker* (*p. s*), also directed downwards, and at its junction with the trunk, on the dorsal surface, is the very small median *anus* (*a*).

The whole body is encircled by close-set transverse grooves, dividing it into *annuli.* These, like the annuli of some earthworms, are more numerous than the true segments or metameres, the study of the internal organs showing that, except at the two extremities, each segment contains five annuli. On the ventral surface of the fifth annulus of each segment is a pair of minute apertures, the *nephridiopores* or excretory apertures (*n. p. 1–17*); of these there are altogether seventeen pairs, marking the fifth rings of the sixth to the twenty-second segments.

The anterior sucker bears on its dorsal surface five pairs of small black spots, the *eyes* (*e. 1*, *e. 5*).

The perfectly definite and comparatively small number of metameres in the leech offers a striking point of contrast

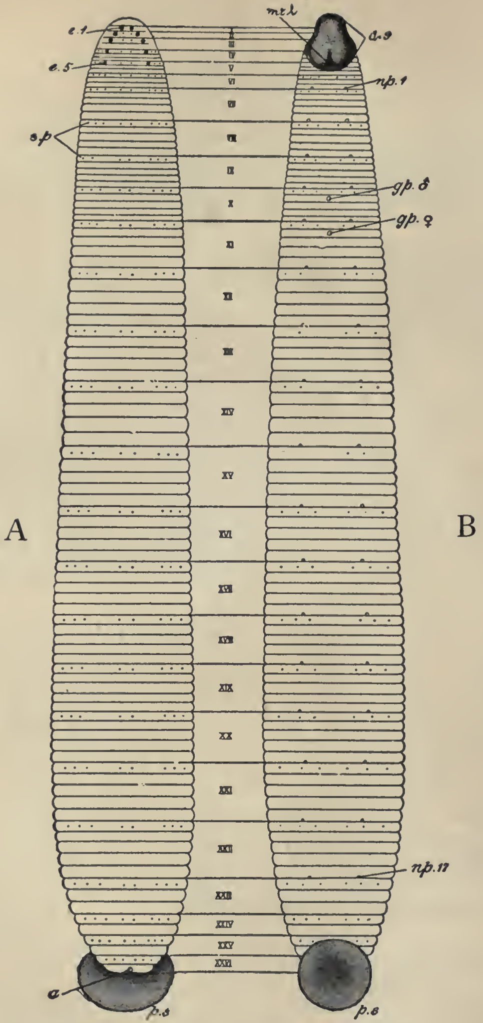
mth
e.1
a.s
e.5
np.1
s.p
gp.♂
gp.♀
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
XIX
XX
XXI
XXII
XXIII
XXIV
XXV
XXVI
A
B
np.17
a
p.s
p.s

FIG. 117. — **Hirudo medicinalis.** A, dorsal; B, ventral aspect. *a*, anus; *a. s*, anterior sucker; *e. 1*, first pair of eyes; *e. 5*, fifth pair; *gp.* ♂, male gonopore; *gp.* ♀, female gonopore; *mth*, mouth; *np. 1*, first pair of nephridiopores; *np. 17*, seventeenth pair; *p. s*, posterior sucker; *s. p*, sensory papillæ; I–XXVI, segments. (Partly after Whitman.)

with what we have met with in the Chætopoda, and is to be looked upon as a mark of higher differentiation.

The *alimentary organs* are greatly modified in accordance with the blood-sucking habits of the animal. Surrounding the mouth are three jaws, one median and dorsal, the other two ventro-lateral. Each has the form of a compressed muscular cushion, with a sharp, evenly curved, free edge covered with chitin, which is produced into numerous serrations or *teeth* (Fig. 118). By means of its muscles each jaw can be moved backwards or forwards through a certain arc, and the three, acting together, produce the characteristic triradiate bite in the skin of the animal upon which the leech preys.

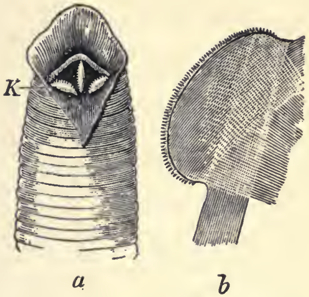

FIG. 118.—*a*, Head of **Hirudo medicinalis**, showing the three jaws (*k*): *b*, one of the jaws isolated, with the finely toothed free edge. (After Sedgwick.)

The mouth leads into a muscular *pharynx* (Fig. 119, *ph*), situated in the fourth to seventh segments. Radiating muscles pass from its walls to the integument, and by their contraction dilate its cavity and suck in blood made by the jaws. Around the pharynx are numerous unicellular *salivary glands*, which open close to the mouth; their secretion has the effect of preventing the coagulation of the blood taken as food.

The pharynx communicates by a very small aperture with the second and largest division of the enteric canal, the huge *crop* (*cr*), a thin-walled tube extending from the eighth to the eighteenth segment, and produced into eleven pairs of lateral pouches (*cr*, *cr. 1*, *11*). The crop is capable of great

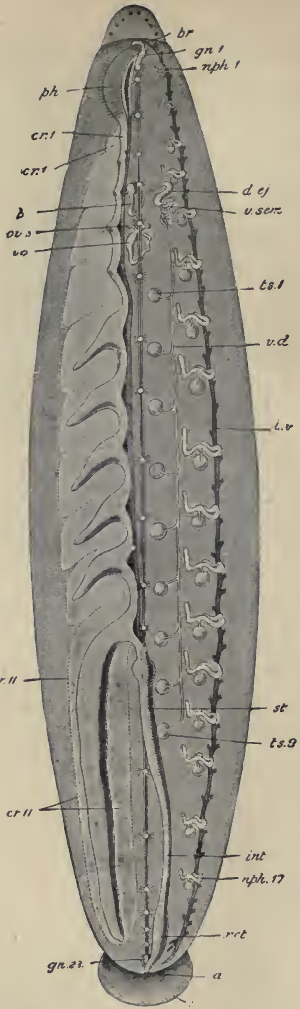
br
gn 1
nph 1
ph
cr.1
cr.1
d. ej
v. sem
p
ov. s
va
ts.1
v.d
l.v
r.11
st
ts.9
cr 11
int
nph. 17
rct
gn.23.
a

FIG. 119.—**Hirudo quinquestriata.** Dissection from the dorsal aspect, *a*, anus; *br*, brain; *cr. I*, first diverticulum of crop, contracted; *cr. I′*, the same expanded; *cr. II*, the last diverticulum of the crop, contracted; *cr. I′*, the same expanded; *d. ej*, ductus ejaculatorius; *gn. 1–23*, ganglia of ventral nerve-cord; *int.* intestine; *l. v*, lateral vessel; *nph. 1–17*, nephridia; *ov. s*, ovarian sac; *p*, penis; *ph*, pharynx; *p. s*, posterior sucker; *rct*, rectum; *st*, stomach; *ts. 1—9*, testes; *va*, vagina; *v. d*, vas deferens; *v. sem*, vesicula seminalis.

dilation, and its form varies greatly according to whether it is empty or gorged with blood. Posteriorly the crop communicates by a minute aperture with the *stomach* (*st*), a tubular chamber which is the digestive portion of the canal; the blood is passed into it from the crop with extreme slowness, and undergoes an immediate change, its colour turning from red to green. The digestion of a whole cropful of blood takes many months. The stomach is continued into a narrow *intestine* (*int*); this passes into a somewhat dilated rectum (*rct*), which turns slightly upwards and opens by the anus (*an*) in the last annulus.

The *excretory system* consists of seventeen pairs of *nephridia* (*nph. 1–17*), situated in segments 6–22. A typical nephridium (Fig. 120) has the general form of a loop passing upwards from the ventral body-wall, produced into an offshoot which extends inwards (mesially) to the corresponding testis, and connected posteriorly with a small bladder or *vesicle* (Fig. 120, *vs*). The free end is swollen into a lobed mass which lies in a blood sinus (Fig. 114, *nst*); comparison with other Hirudinea shows that this dilated end of the nephridium represents a nephrostome which has lost its open funnel-like end in correlation with the absence of a distinct cœlom.

There is a complex *vascular system*, containing, like that of the earthworm, red blood, the plasma coloured with hæmoglobin and containing sparsely distributed colourless corpuscles. But a striking difference from the preceding annelidan types is found in the fact that the blood-containing spaces are of two kinds,—*blood-vessels* proper, having muscular walls, and *blood-sinuses*, the walls of which are devoid of muscle.

The two principal blood-vessels are lateral in position (Figs. 119 and 122, *l. v*), running fore and aft at the level of the middle of the nephridia and uniting with one another at the anterior and posterior ends of the body. They send off branches both dorsally and ventrally, some of which anastomose with one another. The ultimate branches break up into capillaries in the integument, nephridia, etc.

The two principal sinuses are respectively dorsal (*d. s*) and ventral (*v. s*), the former lying just above the enteric canal in the middle dorsal line, the latter occupying a similar position on the ventral side, and enclosing the ventral nerve-cord.

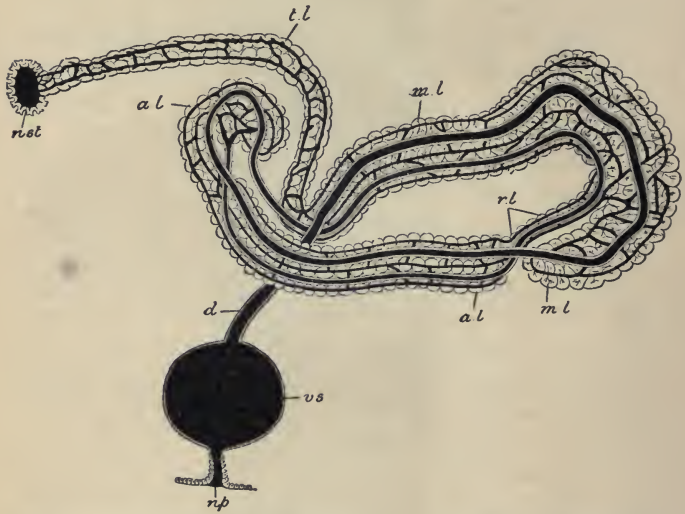

FIG. 120. — Nephridium of the medicinal leech. *a. l*, apical lobe; *m. l*, middle lobe; *n. p*, nephridiopores; *nst*, nephrostome; *r. l*, recurrent lobe; *t. l*, testis lobe; *vs*, vesicle; *vs. d*, vesicle duct. (After Bourne.)

The *nervous system* is of the usual annulate type. There is a small *brain* (Fig. 119, *br*) situated above the anterior end of the pharynx immediately behind the median dorsal jaw. It is connected by a very short pair of œsophageal connectives with the ventral nerve-cord, which consists of twenty-three well-marked rounded ganglia (*gn. 1–23*) united by delicate double connectives. The first, or sub-œsophageal ganglion is larger than the others, and is shown by development to be made up of five united embryonic ganglia: the last ganglion is also of unusual size, and results from the fusion of six distinct ganglia in the embryo. The ventral nerve-cord is contained in the ventral sinus.

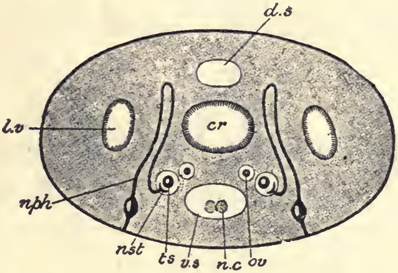

FIG. 121.—Transverse section of *Hirudo:* diagrammatic; *cr*, crop; *d. s*, dorsal sinus which encloses the dorsal vessel; *l. v*, lateral vessel; *n. c*, nerve cord; *nph.*, nephridium; *nst.*, nephrostome; *ov*, ovary; *ts*, testis; *v. s*, ventral sinus. (After Bourne.)

The principal *sense organs* are the *eyes*, of which there are five pairs situated round the margin of the anterior sucker on the dorsal side, one pair in each of the five segments. They occupy positions taken in the succeeding segments by a series of papillæ, the *lateral sense-organs*, with which they are obviously homologous. The margin of the anterior sucker also bears a large number of *goblet-shaped organs*, which are very probably organs of taste. The minute structure both of these and of the lateral sense organs is very similar to that of the eyes. The function of the lateral sense organs is unknown.

The leech is monœcious. There are nine pairs of *testes* (Fig. 119, *ts*), in the form of small spherical sacs situated in segments 12–20. Each gives off from its outer surface a narrow *efferent duct*, which opens into a common *vas deferens* (*v. d*). In the tenth segment the vas deferens increases in width and forms a complex coil, the *vesicula seminalis* (*v. sem*), from which is continued anteriorly a somewhat dilated muscular tube, the *ductus ejaculatorius* (*d. ej*). From each ejaculatory duct a narrow tube passes to the base of the *penis* (*p*), a curved eversible muscular organ which opens on the ventral surface of the second annulus of the tenth segment, in the middle line.

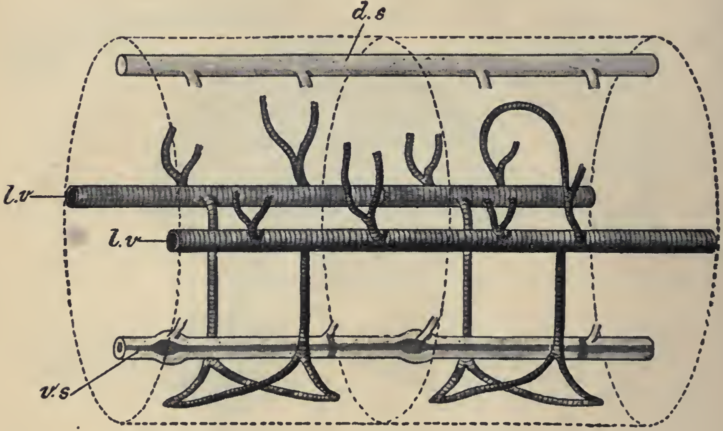

FIG. 122.—Diagram of principal blood channels of leech; *d. s*, dorsal sinus; *l.* lateral vessel; *v. s*, ventral sinus containing nerve-cord.

The *ovaries* are coiled filamentous bodies, each enclosed in a small globular *ovarian sac* (*ov. s*), situated in the eleventh segment. From each ovarian sac a short *oviduct* passes inwards and backwards, and unites with its fellow in a median duct which opens into a curved muscular tube, the *vagina* (*va*), which opens in the middle line on the ventral surface of the second annulus of the eleventh segment, *i.e.*, one segment behind the male aperture.

The leeches are a comparatively uniform group; but some of the class differ from the medicinal leech in more or less important points. Thus in one section there are no jaws, and the anterior end of the body is capable of being retracted within the part immediately behind it or thrust forward as a *proboscis* or *introvert.* In the great majority respiration takes place through the skin, as in the medicinal leech; but in one genus, *Branchellion*, which is an external parasite on certain fishes, gills are present in the form of delicate lateral outgrowths of the segments.

The majority of the Hirudinea are inhabitants of fresh water, and live, like the medicinal leech, by sucking the blood of higher animals. Others are permanent external parasites; others again are carnivorous, feeding on snails and other Mollusca.

SECTION X. — PHYLUM ARTHROPODA

If we examine and compare, even quite superficially, a crayfish, a scorpion, a centipede, and a blue-bottle fly, we see at once that, while they manifestly do not belong to any of the groups of animals studied hitherto, they are all connected together by certain broad common features. They all have a hard, or at least tough, integument; they all have the body more or less clearly divided into segments, and they all have a system of appendages, feelers, jaws, legs, etc., adapted to different uses in the different animals mentioned, and in different parts of the body of the same animal, but agreeing in being covered with a hard or tough integument like that of the body itself, and in being divided into segments by a number of joints. These features, together with certain points in the arrangement and structure of the internal parts, are characteristic of the members of the phylum **Arthropoda**, a group of very great extent, comprising, among others, four large classes, each exemplified by one of the four familiar animals above referred to.

Of these the crayfish differs from the rest in being an aquatic animal and in having organs of respiration, gills, or branchiæ adapted to this mode of life. The remaining three are, with a few exceptions, air-breathers. The crayfish is a representative of the class **Crustacea** of the phylum Arthropoda; the scorpion of the class **Arachnida**, the centipede of the class **Myriapoda**, and the blue-bottle fly of the class **Insecta.**

1. THE CRUSTACEA

The class **Crustacea** comprises a very large number of Arthropods, the great majority of which are inhabitants either of fresh water or of salt. Familiar examples of Crustacea are the crayfishes, lobsters, shrimps, and prawns, the crabs and hermit-crabs, the sand-hoppers, and woodlice, the barnacles, and acorn-shells. As an example of the Crustacea the **Fresh-water Crayfish** should be studied. The following description applies more especially to the common European crayfish (*Potamobia pallipes*),[1] but the American species of *Astacus* will be found to correspond in all essential respects, while the lobster also presents but slight differences.

It is to be noticed, in the first place, that the crayfish, like Nereis, is a bilaterally symmetrical animal, and that the bilateral symmetry is complete, the right and left halves of the body being exactly alike. The crayfish, it is to be noticed, also resembles Nereis and the leech in being metamerically segmented, the segmentation being most clearly distinguishable in the posterior region of the body. Here, however, the external resemblance ceases. Instead of the soft integument of Nereis and the leech, the crayfish has a hard enclosing crust or exoskeleton formed of the thickened and calcified cuticle, and, in place of the unjointed, short parapodia of Nereis, there are a series of variously modified appendages, feelers, jaws, legs, etc., which, like the body itself, are enclosed in a hard exoskeleton, having a jointed character, the appendages thus

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[1] More commonly named *Astacus fluviatilis*.

being divided into series of movable segments which are termed the *podomeres.*

The body of the crayfish (Fig. 123) is divided into two regions — an anterior, the *cephalothorax* (*cth*), which is covered by a broad shield or *carapace;* and a posterior, the *abdomen* (*ab*), which is divided into distinct segments, movable upon one another in a vertical plane. The cephalothorax is again divided into two regions — an anterior, the *head,* and a posterior, the *thorax* — by a transverse depression, the *cervical groove.* The carapace is developed from the dorsal regions of both head and thorax, and is free only at the sides of the thorax,[1] where it forms a flap or *gill-cover*

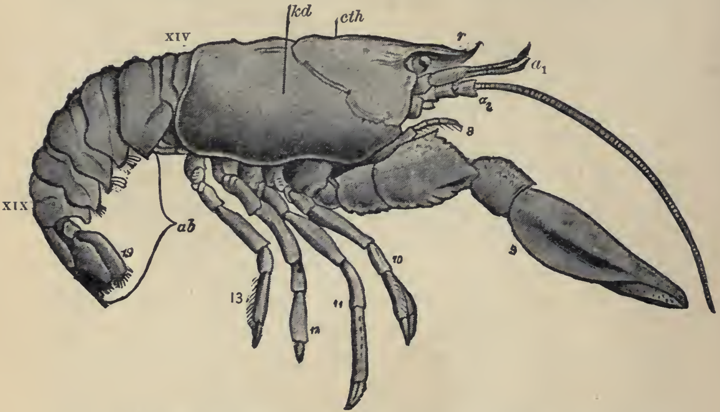

FIG. 123. — **Astacus fluviatilis**, side view of male. a_1, antennule; a_2, antenna; *ab*, abdomen; *cth*, cephalothorax; *kd*, gill-cover; *r*, rostrum; *8*, third maxillipede; *9*, first leg; *10–13*, remaining legs; *19*, uropod; XIV, first abdominal segment; XIX, sixth abdominal segment. (From Lang's *Comparative Anatomy.*)

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[1] This was the view of Huxley, but it is the opinion of American authors that the carapace is the enlargement of the fused tergites or dorsal region of two head-segments, *i.e.*, the second antennal and mandibular; those of the succeeding cephalothoracic segments being atrophied. — AMERICAN EDITOR.

(*kd*) on each side, separated from the actual body-wall by a narrow space in which the gills are contained. The carapace is made of chitin, strongly impregnated with carbonate of lime so as to be hard and but slightly elastic.

The *abdomen* is made up of seven segments: the first six (XIV–XIX) of these are metameres in the strict sense of the word, and have a ring-like form, presenting a broad dorsal region or *tergum;* a narrow ventral region or *sternum;* and downwardly directed lateral processes, the *pleura*. The seventh division of the abdomen is the *telson;* it is reduced in size, flattened horizontally, and divided by a transverse groove into anterior and posterior portions. All seven segments are calcified, and are united to one another by chitinous articular membranes; the first segment is similarly joined to the thorax.

It has been stated that the abdominal segments are movable upon one another in a vertical plane, *i.e.*, the whole abdomen can be *extended* or straightened, and *flexed* or bent under the cephalothorax; the segments are incapable of movement from side to side. This is due to the fact that, while adjacent segments are connected dorsally and ventrally by flexible articular membranes, they present at each side a *hinge*, placed at the junction of the tergum and pleuron, and formed by a little peg-like process of one segment fitting into a depression or socket in the other. A line drawn between the right and left hinges constitutes the *axis of articulation*, and the only possible movement is in a plane at right angles to this axis.

The ventral and lateral regions of the thoracic exoskeleton are produced into the interior of the body in the form of a segmental series of calcified plates, so arranged as to form a row of lateral chambers in which the muscles of the limbs lie, and a median tunnel-like passage or *sternal canal*, containing the thoracic portion of the nervous system. The entire *endophragmal system*, as it is called, constitutes a kind of internal skeleton.

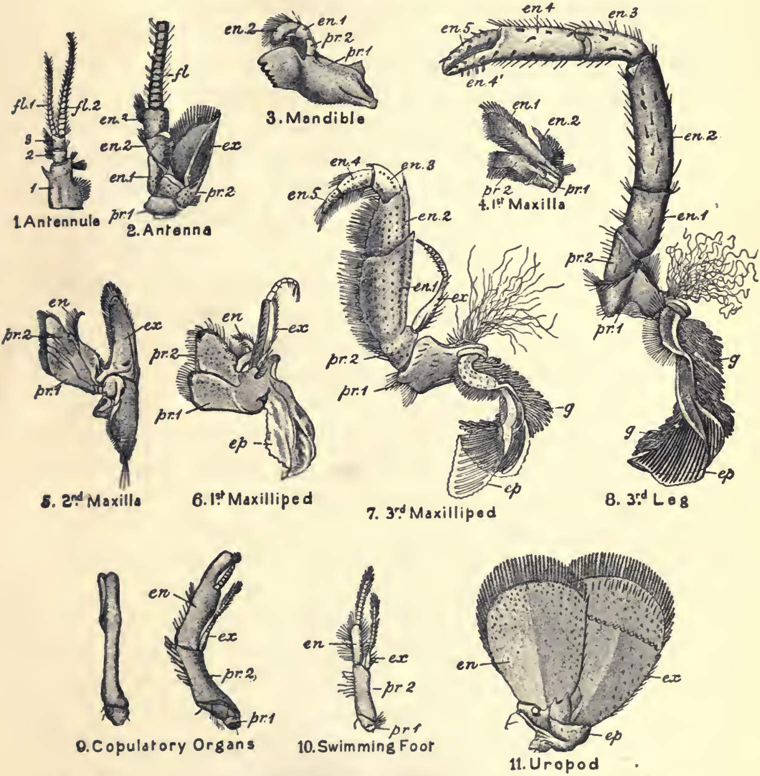
The **head** exhibits no segmentation; its sternal region is formed largely by a shield-shaped plate, the *epistoma*, nearly vertical in position. The ventral surface of the head is, in fact, bent so as to face forwards instead of downwards. The cephalic region of the carapace is produced in front into a large median spine, the *rostrum* (Fig. 123, *r*): immediately below it is a plate from which spring two movably articulated cylindrical bodies, the *eye-stalks*, bearing the eyes at their ends.

Among the *appendages* one's attention is attracted by the long feelers (Fig. 123, a_1, a_2) attached to the head, the five pairs of legs (*9–13*) springing from the thorax, and the little fin-like bodies arising from the sterna of the abdomen. It will be convenient to begin with the last-named region.

The third, fourth, and fifth segments of the abdomen bear each a pair of small appendages, the abdominal feet or *pleopods* (Fig. 124, *10*). Each consists of an axis or *protopodite*, consisting of a very short proximal (*pr. 1*) and a long distal (*pr. 2*) podomere, and bearing at its free end two jointed plates, fringed with setæ, the *endopodite* (*en*) and *exopodite* (*ex*). These appendages act as fins, moving backwards and forwards with a regular swing, and probably aiding in the animal's forward movements.

In the female a similar appendage is borne on the second segment, while that of the first is more or less rudimentary. In the male the first and second pleopods (*9*) are modified into incomplete tubes which act as copulatory organs (*gonopoda*). The sixth pair of abdominal limbs (*11*) are alike in the two sexes; they are very large, both endo-

and exopodite having the form of broad flat plates; in the natural position of the parts they lie one on each side of the telson, forming with it a large five-lobed tail-fin; they are therefore conveniently called *uropods* or tail-feet. The telson itself bears no appendages.


1. Antennule 2. Antenna 3. Mandible 4. 1st Maxilla 5. 2nd Maxilla 6. 1st Maxilliped 7. 3rd Maxilliped 8. 3rd Leg 9. Copulatory Organs 10. Swimming Foot 11. Uropod
fl.1
fl.2
3
2
1
fl
en.3
en.2
en.1
ex
pr.2
pr.1
en.2
en.1
pr.2
pr.1
en.4
en.3
en.5
en.4'
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ex
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ep
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FIG. 124. — Typical appendages of **Astacus**. *en. 1–5*, podomeres of endopodite; *ep*, epipodite; *ex*, exopodite; *fl.* flagella; *g*, gill; *pr. 1*, *pr. 2*, podomeres of protopodite; *1–3*, podomeres of axis of antennule. (After Huxley.)

The thoracic appendages are very different. The four posterior segments bear long, slender jointed *legs* (*8*), upon which the animal walks; in front of these is a pair of very large legs terminating in huge claws or *chelæ*, and hence called *chelipeds* (Fig. 123, *9*). The three anterior segments[1] bear much smaller appendages, more or less leg-like in form, but having their bases toothed to serve as jaws; they are distinguishable as *maxillipeds* or foot-jaws (Fig. 124, *6*, *7*).

The structure of these appendages is best understood by a consideration of the *third maxilliped* (*7*). The main portion of the limb is formed of seven podomeres arranged in a single series, strongly calcified, and, with the exception of the second and third, which are fused, movably articulated with one another. The second podomere, counting from the proximal end, bears a many-jointed, feeler-like organ (*ex*), and from the first springs a thin folded plate (*cp*), having a plume-like gill (*g*) attached to it. Obviously such an appendage is biramous, but with one of its branches greatly in excess of the other; the first two segments of the axis (*pr. 1*, *pr. 2*) form the protopodite, its remaining five segments (*en. 1–5*) the endopodite, and the feeler, which is directed outwards, or away from the median plane, the exopodite (*ex*). The folded plate (*ep*) is called the *epipodite;* in the natural position of the parts it is directed upwards, and lies in the gill-cavity between the proper wall of the thorax and the gill-cover.

The five *legs* (*8*) differ from the third maxilliped in their greater size, and in having no exopodite; in the fifth or last the epipodite also is absent. The first three of them have undergone a curious modification, by which their ends are

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[1] By most authors the maxillipedes are regarded as belonging to the head, the number of pairs of thoracic appendages being considered as five.—AMERICAN EDITOR.

converted into pincers or *chelæ;* the fourth segment (*en. 4*) of the endopodite (sixth of the entire limb) is produced distally so as to form a claw-like projection (*en. 4'*), against which the terminal segment (*en. 5*) bites. The first leg is much shorter than any of the others and its chela is of immense size, and forms an important weapon of offence and defence. The *second maxilliped* resembles the third, but is considerably smaller; the *first* (*6*) has its endopodite greatly reduced, the two segments of its protopodite large and leaf-like, and no gill is connected with the epipodite.

The head bears a pair of mandibles and two pairs of maxillæ in relation with the mouth, and in front of that aperture a pair of antennules and one of antennæ. The hindmost appendage of the head is the *second maxilla* (*5*), a markedly foliaceous appendage; its protopodite (*pr. 1*, *pr. 2*) is cut up into lobes; the exopodite (*ex*) is modified into a boomerang-shaped plate, which, we shall see, is an important accessory organ of respiration. The *first maxilla* (*4*) is a very small organ, having neither exo- or epipodite. The *mandible* (*3*) is a large, strongly calcified body, toothed along its inner edge, and bearing on its anterior border a little three-jointed, feeler-like body, the *palp*.

The *antenna* (*2*) is of great size, being nearly as long as the whole body. It consists of an axis of five podomeres, the fifth or last of which bears a long, flexible, many-jointed structure, or *flagellum* (*fl*), while from the second segment springs a scale-like body or *squame* (*ex*).

The *antennule* (*1*) has an axis of three podomeres (*1–3*), ending in two many-jointed flagella (*fl. 1* and *2*).

The *eye-stalks*, already noticed, arise just above the antennules, and are formed each of a small proximal and a large distal segment. They are sometimes counted as appendages serially homologous with the antennæ, legs, etc.

If, as seems probable, the eye-stalks and antennules are to be looked upon as belonging to a preoral region corresponding to the prostomium, of Nereis, then it will be seen that the body of the crayfish consists of a prostomium, eighteen metameres, and a telson. The prostomium bears eye-stalks and antennules; the first four metameres are fused with the prostomium to form the head, and bear the antennæ, mandibles, first maxillæ, and second maxillæ; the next eight metameres (5th–12th), constitute the thorax, and bear the three pairs of maxillipeds and the five pairs of legs; the remaining six metameres (13th–18th), together with the telson, constitute the abdomen, and bear five pairs of pleopods and one of uropods.

The *digestive organs* (Fig. 125) are somewhat complicated. The *mouth* lies in the middle ventral line of the head, and is bounded in front by the labrum, at the sides by the mandibles, and behind by a pair of delicate lobes, the *paragnatha*. It leads by a short wide *gullet* (*œ*) into a capacious *stomach*, which occupies a great part of the interior of the head, and is divided into a large anterior or *cardiac division* (*c. s*), and a small posterior or *pyloric division* (*ps*); the latter passes into a narrow and very short *small intestine* (*md*), from which a somewhat wider *large intestine* (*hd*) extends to the *anus* (*an*), situated on the ventral surface of the telson.

In the cardiac division of the stomach the chitinous lining is thickened and calcified in certain parts, so as to form a complex articulated framework, the *gastric mill*, on which are borne a median and two lateral *teeth*, strongly calcified and projecting into the cavity of the stomach. Two pairs of strong muscles arise from the carapace, and are inserted into the stomach; when they contract they move the mill in such a way that the three teeth meet in the middle and complete the comminution of the food begun by the jaws. The

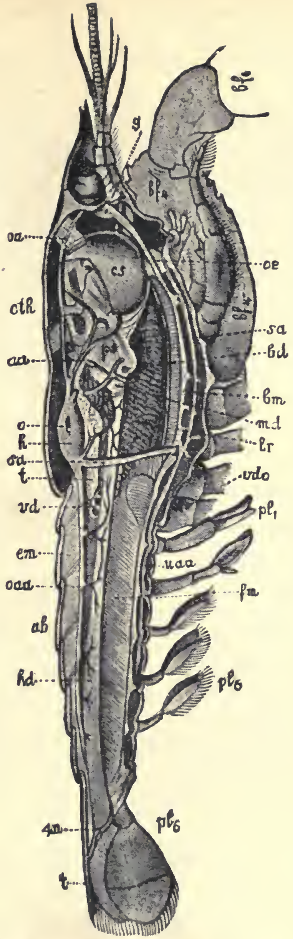
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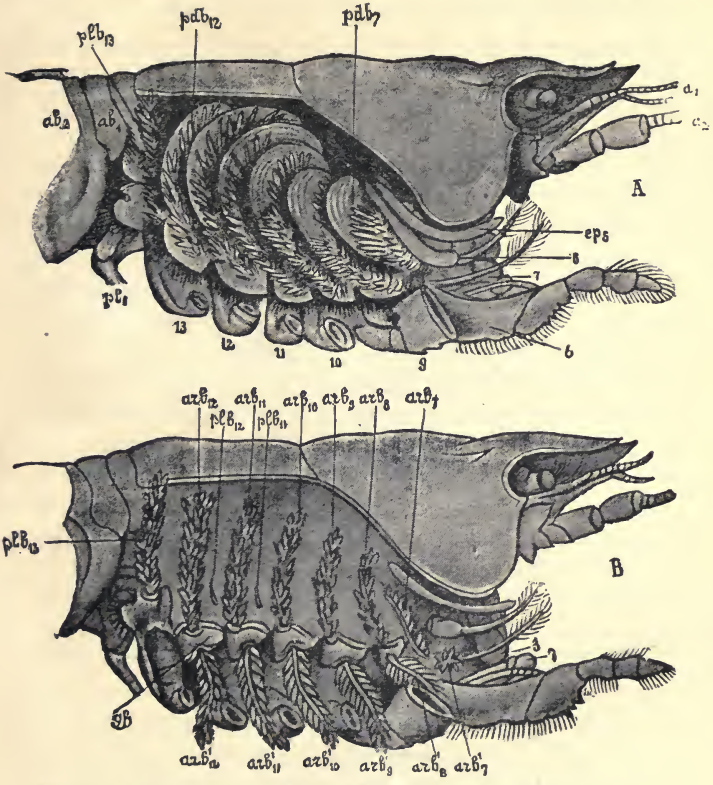
FIG. 125.—**Astacus fluviatilis**, dissection from the right side. *aa*, antennary artery; *ab*, abdomen; *an*, anus; *b. d*, bile duct; *bf. 4*, cheliped; *bm*, ventral nerve-cord; *cs*, cardiac division of stomach; *cth*, cephalo-thorax: *em*, dorsal muscles; *fm*, ventral mucles; *g*, brain; *h*, heart; *hd*, large intestine; *lr*, liver; *md*, small intestine; *o*, ostium; *oa*, ophthalmic artery; *oaa*, superior abdominal artery; *æ*, gullet; *pl. 1-5*, pleopods; *pl. 6*, uropod; *ps*, pyloric division of stomach; *sa*, sternal artery; *t*, testis and telson; *uaa*, inferior abdominal artery; *vd*, vas deferens; *vdo*, male genital aperture. (From Lang after Huxley.)

separation of the teeth is effected partly by the elasticity of the mill, partly by delicate muscles in the walls of the stomach. The pyloric division of the stomach forms a strainer; its walls are thickened and produced into numerous setæ, which extend quite across the narrow lumen and prevent the passage of any but finely divided particles into the intestine. Thus the stomach has no digestive function, but is merely a masticating and straining apparatus. On each side of the cardiac division is found at certain seasons of the year a plano-convex mass of calcareous matter, the *gastrolith*.

The digestion of the food and to some extent the absorption of the digested products are performed by a pair of large glands (*lr*), lying one on each side of the stomach and anterior end of the intestine. They are formed of finger-like sacs or *cæca*, which discharge into wide ducts opening into the small intestine, and are lined with glandular epithelium derived from the endoderm of the embryo. The glands are often called livers, but as the yellow fluid they secrete digests proteids as well as fat, the name *hepato-pancreas* is often applied to them, or they may be called simply *digestive glands*. The crayfish is carnivorous, its food consisting largely of decaying animal matter.

The digestive organs and other viscera are surrounded by a *body-cavity*, which is in free communication with the blood-vessels and itself contains blood.

There are well-developed *respiratory organs*, in the form of *gills*, contained in a narrow branchial chamber, bounded internally by the proper wall of the thorax (Fig. 127, *ep*), externally by the gill-cover or pleural region of the carapace (*kd*). Each gill consists of a stem giving off numerous branchial filaments, so that the whole organ is plume-like. The filaments are hollow, and communicate with two paral-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9
arb12
arb11
arb10
arb9
arb8
arb7
plb12
plb11
plb13
B
8
7
9b
arb'12
arb'11
arb'10
arb'9
arb'8
arb'7

FIG. 126. — Respiratory organs of **Astacus fluviatilis.** In A the gill-cover is removed and the gills undisturbed; in B the podobranchiæ are removed and the outer arthrobranchiæ turned down. a_1, antennule; a_2, antenna; ab_1, first; ab_2, second abdominal segment; *arb. 7–12*, inner arthrobranchiæ; arb_1. *7 12*, outer arthrobranchiæ: *ep. 5*, scaphognathite; *plb. 11–13*, pleurobranchiæ; *pdb. 7–13*, podobranchs; *pl. 1*, first pleopod; *6–13*, thoracic appendages. (From Lang's *Comparative Anatomy*, after Huxley.)

lel canals in the stem — an external, the *afferent branchial vein*, and an internal, the *efferent branchial vein*.

According to their point of origin, the gills (Fig. 126) are divisible into three sets,—first, *podobranchiæ* or foot-gills, springing from the epipodites of the thoracic appendages, from which they are only partially separable; secondly, *arthrobranchiæ* or joint-gills, springing from the articular membranes connecting the thoracic appendages with the trunk; and thirdly, *pleurobranchiæ* or wall-gills, springing from the lateral walls of the thorax, above the attachment of the appendages.

At the base of each antenna is an organ of a greenish colour, the *antennary* or *green gland*, by which the function of renal excretion is performed. The gland is cushion-shaped; it discharges into a thin-walled sac or *urinary bladder* which opens by a duct on the proximal segment of the antenna. The glands already referred to as occurring in the gills are also supposed to have an excretory function.

The *circulatory organs* are in a high state of development. The *heart* (Figs. 125, 127, *h*) is situated in the dorsal region of the thorax, and is a roughly polygonal muscular organ pierced by three pairs of apertures or *ostia* (*o*) guarded by valves which open inwards. It is enclosed in a spacious *pericardial sinus* (Fig. 127, *pc*), which contains blood. From the heart spring a number of narrow tubes, called *arteries*, which serve to convey the blood to various parts of the body. At the origin of each artery from the heart are valves which allow of the flow of the blood in one direction only, viz., from the heart to the artery. From the anterior end of the heart arise five vessels, and from the posterior end two, which are practically united at their origin.

All these arteries branch extensively in the various organs they supply, becoming divided into smaller and smaller offshoots, which finally end in microscopic vessels called *capillaries*. These latter end by open mouths which communicate with the *blood-sinuses* (Fig. 128, *s*), spacious cavities lying among the muscles and viscera, and all communicating, mediately or immediately, with the *sternal sinus* (*st. s*), a great median canal running longitudinally along the thorax and abdomen, and containing the ventral nerve-cord and the sternal and ventral abdominal arteries. In the thorax the sternal sinus sends an offshoot to each gill in the form of a well-defined vessel, which passes up the outer side of the gill and is called the *afferent branchial vein* (*af. br. v*; see also Fig. 127). Spaces in the gill-filaments

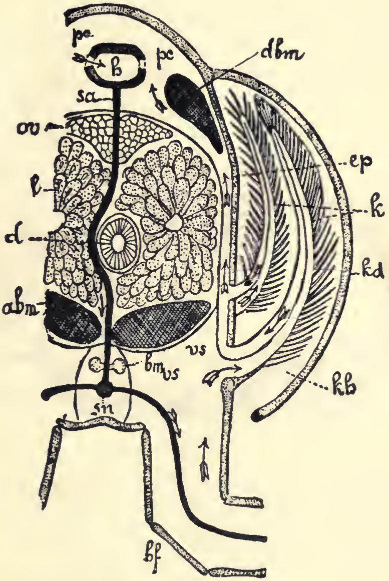


FIG. 127.—Transverse section of thorax of crayfish, diagrammatic. *abm*, ventral abdominal muscles; *bf*, leg; *bm*, ventral nerve-cord; *d*, intestine; *dbm*, dorsal muscles of abdomen; *ep*, wall of thorax; *h*, heart; *k*, gills; *kd*, gill-cover; *l*, liver; *ov*, ovary; *pc*, pericardial sinus; *sa. sn*, sternal artery; *vs*, ventral sinus. The arrow shows the direction of the blood-current. (From Lang's *Comparative Anatomy*.)

place the afferent in communication with the *efferent branchial vein* (*ef. br. v*), which occupies the inner side of the gill-stem. The efferent branchial veins open into six *branchio-cardiac veins* (*br. c. v*), which pass dorsally in close contact with the lateral wall of the thorax and open into the pericardial sinus (*pcd. s*).

The whole of this system of cavities is full of blood, and the heart is rhythmically contractile. When it contracts, the blood contained in it is prevented from entering the pericardial sinus by the closure of the valves of the ostia, and therefore takes the only other course open to it, viz., into the arteries. When the heart relaxes, the blood in the arteries is prevented from regurgitating by the valves at their origins, and the pressure of blood in the pericardial sinus forces open the valves of the ostia and so fills the heart. Thus in virtue of the successive contractions of the heart, and of the disposition of the valves, the blood is kept con-

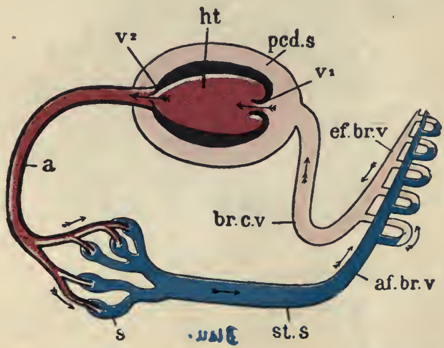


Fig. 128.—Diagram of the circulation in the crayfish; heart and arteries, scarlet; veins and sinuses containing non-aërated blood, blue; those containing aërated blood, pink. *a*, artery; *af. br. v*, afferent branchial vein; *br. c v*, branchio-cardiac vein; *ef. br. v*, efferent branchial vein; *ht*, heart; *pcd s*, pericardial sinus; *s*, sinus; *st. s*, sternal sinus; v^1, ostium with valves; v^2, arterial valves. The arrows show the direction of the current.

stantly moving in one direction, viz., from the heart by the arteries to the various organs of the body, where it receives carbonic acid and other waste matters; thence by sinuses into the great sternal sinus; from the sternal sinus by afferent branchial veins to the gills, where it exchanges carbonic acid for oxygen; from the gills by efferent branchial veins to the branchiocardiac veins, thence into the pericardial sinus, and so to the heart once more.

The **nervous system** (Fig. 129) consists of a brain (*g*) and a ventral nerve-cord, united by œsophageal connectives (*sc*). The ventral cord is double, but the right and left halves have undergone partial fusion, so that the ganglia, and in the abdomen the connectives also, appear single instead of double. The ventral cord contains twelve of these ganglia, the first is infra-œsophageal, being larger than the others and formed by the union of the ganglia belonging to the last three cephalic and first three thoracic segments. All the remaining segments have their own ganglia, with the exception of the telson, which is supplied from the ganglion of the preceding segment. There is a *visceral system* of nerves (*s*) supplying the stomach, originating in part from the brain and in part from the œsophageal connectives.

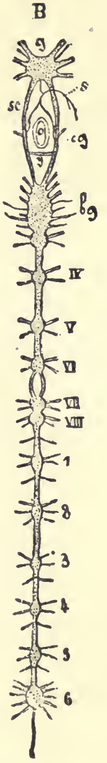


Fig. 129.—Nervous system of **Astacus fluviatilis.** *bg*, sub-œsophageal ganglion; *cs*, commissural ganglion; *g*, brain; *s*, visceral nerve; *sc*, œsophageal connective; *y*, post-œsophageal commissure; IV–VIII, thoracic ganglia; *1–6*, abdominal ganglia. (From Lang's *Comparative Anatomy*, after Vogt and Yung.)

Sensory organs. — The eyes differ entirely in structure from those of any animal that has been described hitherto. Each is a compound structure, being made up of a large number of distinct elements termed the *ommatidea*. The chitinous cuticle covering the distal end of the eye-stalk is transparent, divided by delicate lines into square areas or *facets*, and constitutes the *cornea*. Each facet of the cornea marks the position of the outer end of an ommatideum, optically separated from its neighbours by black pigment.

The antennules contain two sensory organs, to which are assigned the functions of smell and hearing respectively. The *olfactory organ* is constituted by a number of extremely delicate *olfactory setæ*, borne on the external flagellum. The *auditory organ* is a sac formed by invagination of the dorsal surface of the proximal segment, and is in free communication with the surrounding water by a small aperture.

Reproduction. — The crayfish is diœcious, and presents a very obvious sexual dimorphism. The abdomen of the female is much broader than that of the male; the first and second pleopods of the male are modified into tubular or rather spout-like copulatory organs (Fig. 124, *9*); and the reproductive aperture is situated in the male on the proximal podomere of the fifth leg, in the female on that of the third.

The *testis* (Fig. 130, B, *t*, *u*) lies in the thorax, just beneath the floor of the pericardial sinus, and consists of paired anterior lobes (*t*) and an unpaired posterior lobe (*u*). From each side goes off a convoluted *vas deferens* (*vd*), which opens on the proximal segment of the last leg. The *sperms* are curious non-motile bodies produced into a number of stiff processes; they are aggregated into vermicelli-like *spermatophores* by a secretion of the vas deferens.

The *ovary* (A, *ov*, *u*) is also a three-lobed body, and is similarly situated to the testis; from each side proceeds a thin-walled *oviduct* (*od*), which passes downwards, without convolutions, to open on the proximal segment of the third or antepenultimate leg. The eggs are of considerable size.

The ova, when laid, are fastened to the setæ on the pleopods of the female by the sticky secretion of glands occurring both on those appendages and on the segments themselves; they are fertilised immediately after laying, the male depositing spermatophores on the ventral surface of the female's body just before oviposition.

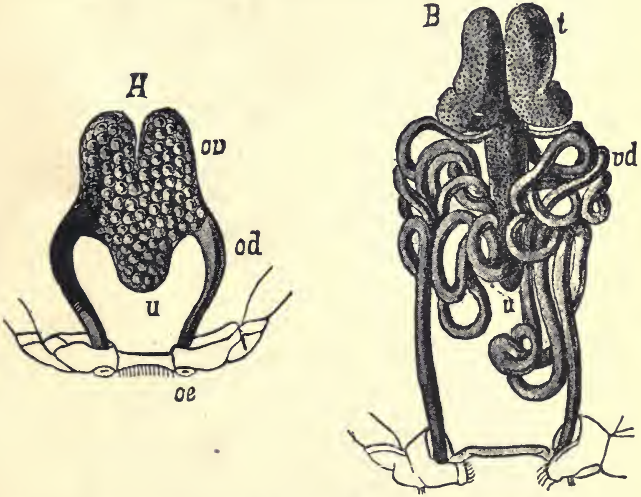
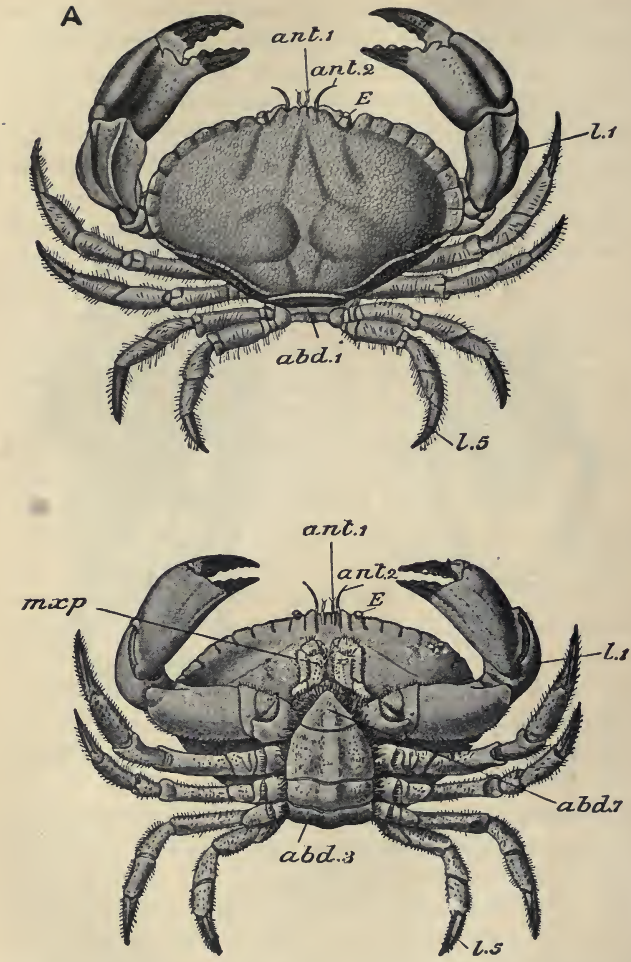


FIG. 130. — Reproductive organs of **Astacus fluviatilis.** A, female; B, male; *od*, oviduct; *oe*, external opening of the same; *ov*, ovary; *t*, testis; *u*, unpaired posterior portion of gonad; *vd*, vas deferens. (From Lang's *Comparative Anatomy*, after Huxley.)

The lobsters, shrimps, prawns, crabs, and hermit-crabs all resemble the crayfish in the number and disposition of the segments, the presence of a carapace covering both head and thorax, the general structure and arrangement of


A
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ant.2
E
l.1
abd.1
l.5
ant.1
ant.2
mxp
E
l.1
abd.7
abd.3
l.5

FIG. 131.—**Cancer pagurus.** A, dorsal; B, ventral aspect. *ant. 1*, antennule; *ant. 2*, antenna; *abd. 1*, *abd. 3*, *abd. 7*, abdominal segments; *E*, eye-stalk; *l. 1*, *l. 5*, legs; *mxp. 3*, third maxillipedes. (A, after Bell.)

the appendages, and the essential features of the internal anatomy. The crabs and the hermit-crabs differ from the other forms mentioned, mainly in the abdomen being reduced. In the crabs (Fig. 131) this region is extremely small, its appendages are only feebly developed, and it is permanently flexed on the sternal surface of the cephalothorax, so that it is completely concealed from view when the animal is looked at from above.[1] In the hermit-crabs

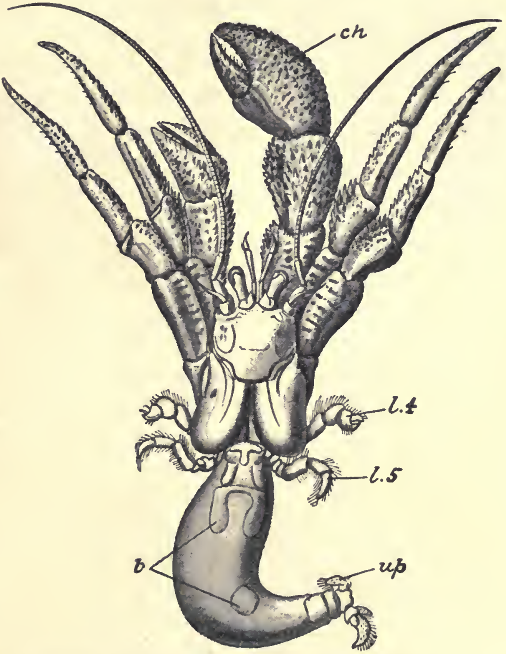

FIG. 132.—**Pagurus bernhardus.** *ch*, chela of first right leg; *l. 4*, *l. 5*, fourth and fifth legs; *t*, abdominal terga; *up*, uropods. (After Bell.)

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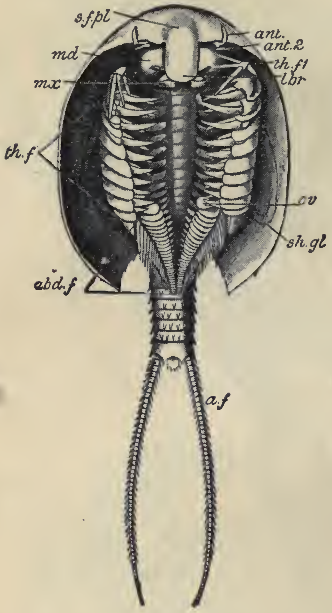
[1] The European Cancer is represented by our common *Cancer irroratus*, and the explanation of Fig. 131 will equally well apply to our species.

(Fig. 132) the abdomen with its appendages is imperfectly developed, and not enclosed completely in a hard exoskeleton, this region being sheltered in the shell of a whelk or other univalve mollusc which the hermit-crab drags about with it.[1]



133.—**Apus glacialis**, ventral aspect. *abd. f*, abdominal feet; *ant. 1*, antennule; *ant. 2*, antenna; *lbr*, labrum; *md*, mandible; *mx*, first maxilla; *ov*, aperture of oviduct; *s. f. pl*, sub-frontal plate; *sh. gl*, shell-gland; *th. f*, thoracic feet; *th. f. 1*, first thoracic foot. (After Bernard.)

The crustaceans enumerated above, together with the sand-hoppers, woodlice and their allies, and a large number of others, form one or two sub-classes into which the class Crustacea is divided—the sub-class **Malacostraca**. The Malacostraca are highly organised Crustacea, usually of considerable size, and nearly all have a thorax of eight and an abdomen of seven segments. The appendages are highly differentiated. There is a gastric mill, and the renal organs are in the form of antennary glands.

The other sub-class is the **Entomostraca**. The Entomostraca, which are even more numerous than the Malacostraca, are of comparatively simple organisation, and usually of small, often almost microscopic, size. The

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[1] Our common American hermit-crab is *Eupagurus pollicaris;* the right chela is still larger than in *Pagurus bernhardus* of the European coast.

number of segments is variable, and the appendages are not so highly differentiated as in the Malacostraca. A carapace developed from the head is often present. There is no gastric mill, and the renal organs are not antennary glands, but *shell-glands* opening at the bases of the second maxillæ. The larva nearly always leaves the egg as a characteristic form called the *Nauplius* (Fig. 134, A), which occurs also, though

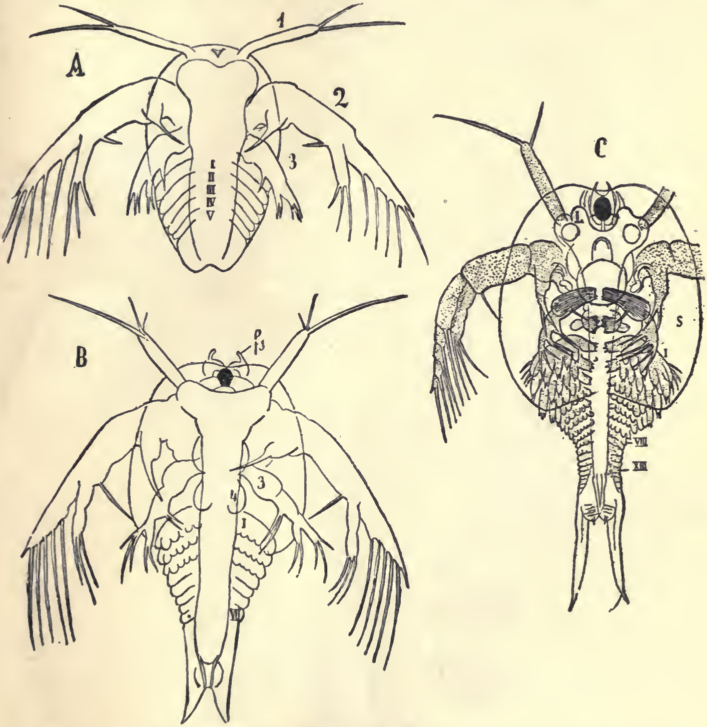
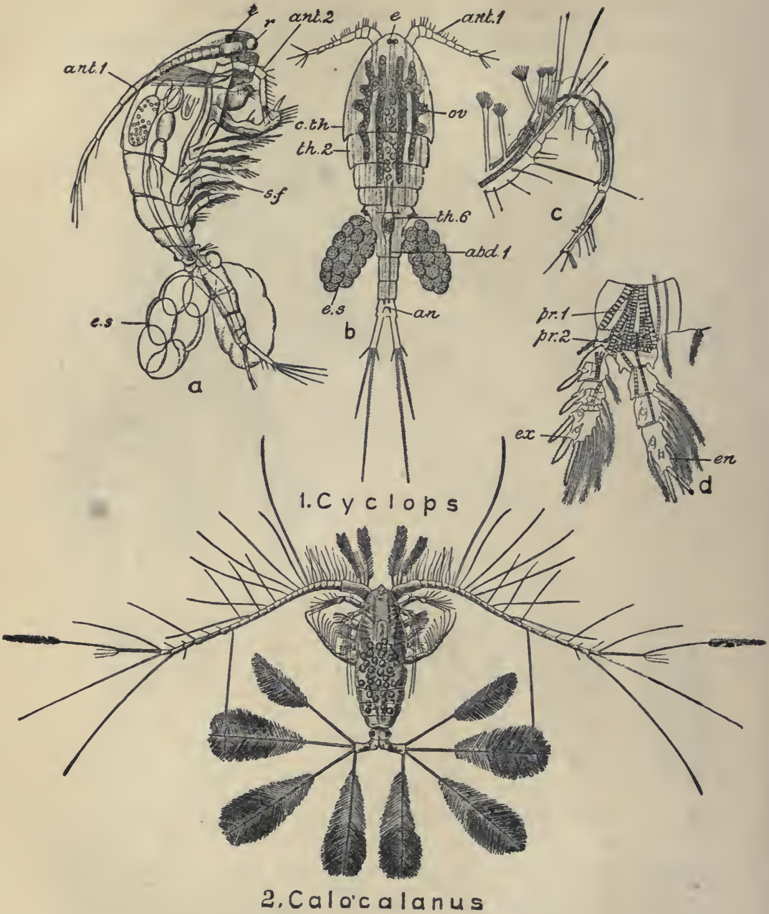


FIG. 134. — Three stages in the development of **Apus**. *fs*, frontal sensory organ; L, digestive gland; *s*, carapace; *1-4*, cephalic appendages; I-XIII, body segments and appendages. (From Lang's *Comparative Anatomy*.)


e
r
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an
a
b
c
pr.1
pr.2
ex
en
d
1. Cyclops
2. Calocalanus

FIG. 135.—*1a*, female **Cyclops**, from the right side; *b*, dorsal view; C, antenna of male; D, swimming-foot. *abd 1*, first abdominal segment; *ant. 1*, antennule; *ant. 2*, antenna; *c. th*, cephalo-thorax; *e*, median eye; *en*, endopodite; *e. s*, egg-sac; *ex*, expodite; *ov*, ovary; *pr. 1*, *pr. 2*, protopodite; *r*, rostrum; *s. f*, swimming-feet; *th. 2*, *th. 6*, thoracic segments. (After Huxley, Gerstaecker, Hartog, and Giesbrecht.)

exceptionally, as a free-swimming stage in the Malacostraca, the Nauplius stage in that sub-class being usually passed through in the egg. The Nauplius is an oval unsegmented body with a median eye, and three pairs of short appendages provided terminally with long hairs.

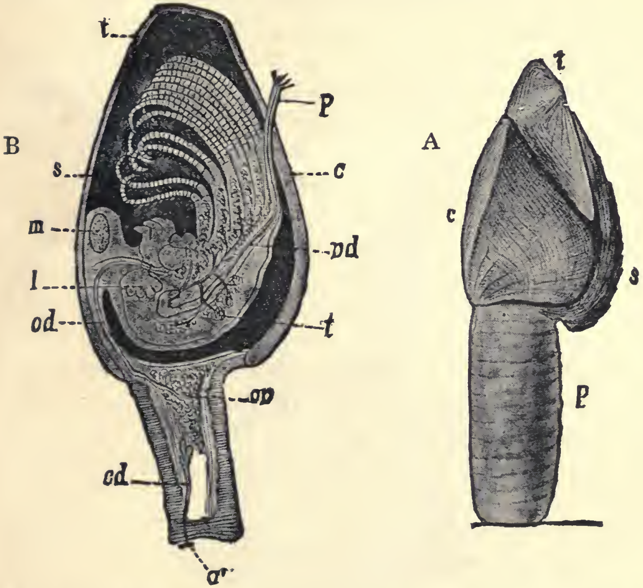


Fig. 136. — **Lepas anatifera.** A, the entire animal; B, its anatomy. *a′*, antennule; *c*, carina; *cd*, cement gland; *l*, digestive gland; *m*, adductor muscle; *od*, oviduct; *ov*, ovary; *p*, (in B) penis and (in A) peduncle; *s*, scutum; *t*, tergum and testis; *vd*, vas deferens. (From Lang's *Comparative Anatomy*, after Darwin and Claus.)

Most of the Entomostraca are free-swimming, and the majority of them, such as the water-fleas (Fig. 135) and their allies, are of almost microscopic minuteness, though a few, such as *Apus* and the brine-shrimp, are of comparatively large size. Many Entomostraca, however, become fixed in the adult condition as external parasites, mainly of fishes. Many of those parasitic Entomostraca undergo a degradation of structure, a *retrograde metamorphosis*, as it is termed. Comparatively highly organised in their free-swimming larval stages, these lose when they attain the adult parasitic condition some, if not all, of their characteristic crustacean features, and may lose all trace of segmentation and of jointed appendages. Also characterised by degradation of structure, though in a less degree than some of the parasitic forms, are the barnacles (Fig. 136) and acorn-shells (*Cirripedes*), which are not parasitic, but are permanently fixed in the adult condition to a rock or a beam of timber or other submerged object. In the larval condition these are free-swimming, distinctly segmented, and provided with a number of jointed appendages; in the adult state they become fixed, lose their segmentation, though retaining some of their jointed appendages, and become enclosed in a fold of the integument in which are developed a series of calcareous plates. The attachment of the cirripede is by the head; while the posterior portion of the body is free, and is capable of being thrust out with a series of six pairs of many-jointed appendages or *cirri*, borne on the thorax through a slit in the enclosing shell. In the barnacles the head-region is drawn out into a stalk (A, *p*); in the acorn-shells the stalk is absent.

2. ONYCHOPHORA

The class **Onychophora** comprises only the aberrant genus **Peripatus**, which is interesting owing to certain primitive features which it presents —features which afford some reason for regarding it as intermediate between such forms as the Annulata on the one hand, and the higher Arthropoda on the other.

Peripatus (Fig. 137) is a caterpillar-like animal of approximately cylindrical form, and not divided into segments; it has a fairly well-marked head and a series (14–42) of short stumpy appendages. The integument is thrown into a number of fine transverse wrinkles and is beset with numerous conical papillæ, each capped with a little chitinous spine. The head (Fig. 138) bears a pair of antennæ, a pair of eyes, a pair of jaws, and a pair of short processes — the *oral papillæ*. On the surface of the oral papillæ are situated a pair of glands, the *slime glands.*

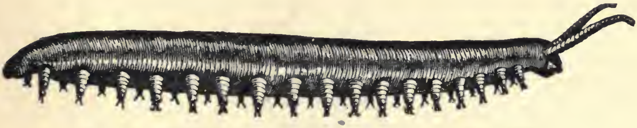


FIG. 137. — **Peripatus capensis**, lateral view. (From Balfour.)

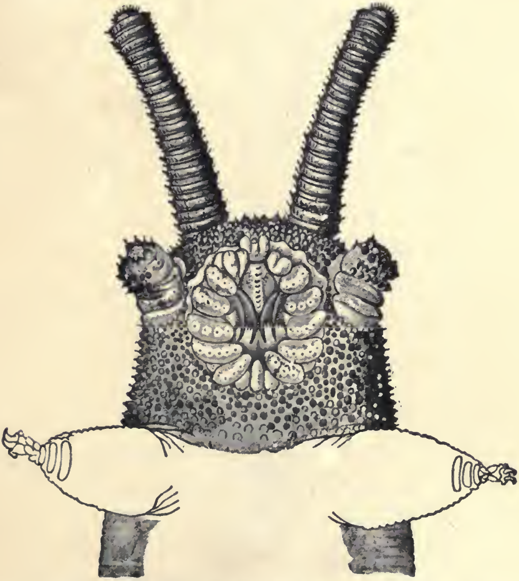
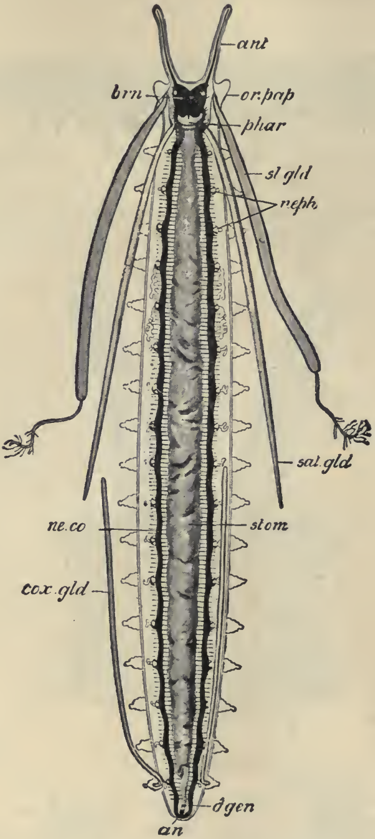


FIG. 138. — Ventral view of head of **Peripatus capensis**, with antennæ, jaws, oral papillæ, and first pair of legs. (After Balfour.)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sal.gld
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♂gen
an

FIG. 139. — Dorsal view of the internal organs of **Peripatus**. *an*, anus; *ant*, antennæ; *brn*, brain; *cox. gld*, coxal gland of the seventeenth leg; ♂ *gen*, male genital aperture; *ne. co*, nerve-cord; *neph*, nephridia; *phar*, pharynx; *sal. gld*, salivary gland; *sl. gld*, slime gland; *stom*, stomach. (Combined from Balfour.)

Each *jaw* is composed of two curved, falciform, chitinous plates; they lie at the sides of the mouth enclosed by a circular lip. The jaws, as well as the oral papillæ, are developed as modified limbs. The *legs* are not jointed; each consists of a proximal part and a small distal part or foot, terminating in a pair of horny claws.

In the internal anatomy (Fig. 139) the most important features are the presence of organs of respiration in the form of tracheæ, unbranched or little branched tubes, groups of which open on little depressions of the integument, the external openings or *stigmata* of which are in some species distributed irregularly over the surface, in others arranged in longitudinal rows; the presence of a series of pairs of nephridia (*neph*) similar to those of the Annulata, and of a nervous system consisting of a brain (*brn*), situated in the head, and two widely separate nerve cords (*ne. co*) which run parallel with one another throughout the length of the body, and are not dilated into distinct ganglia. The sexes are distinct.

The various species of Peripatus are all terrestrial, and are found in damp localities under bark, or dead timber, or stones. Four species occur in South Africa, one in South America, and one in the West Indies, one in New Zealand, and two in Australia.

3. THE MYRIAPODA

The class **Myriapoda**, including the centipedes and the millipedes, consists of tracheate Arthropoda, which bear many features of resemblance to the insects. There is a distinct head, bearing a single pair of many-jointed antennæ, a pair of eyes, and from two to four pairs of jaws; and a trunk, not distinguishable into regions, but consisting of a number of similar segments, each bearing either one pair of legs or two. A system of air-tubes or tracheæ similar to those of Peripatus or the insects open by a series of stigmata (in centipedes on alternate segments) on the sides or lower surfaces of the segments.

The *head* in the Myriapoda (Fig. 140) is as well marked off as in an insect; it appears to be composed of about four fused segments. The *antennæ* consist sometimes of many, sometimes of comparatively few segments. A pair of *eyes*, situated on the dorsal surface of the head, consist of aggregations of ocelli except in *Scutigera*, in which there are compound eyes, differing, however, in their structure from those of insects. There are in millipedes a movable *labrum*, a pair of *mandibles*, and a pair of fused *maxillæ*. In the centipede there are three pairs of jaws in front of the poison-fangs. The mandibles have no palps; one or both pairs of maxillæ usually possess palps.

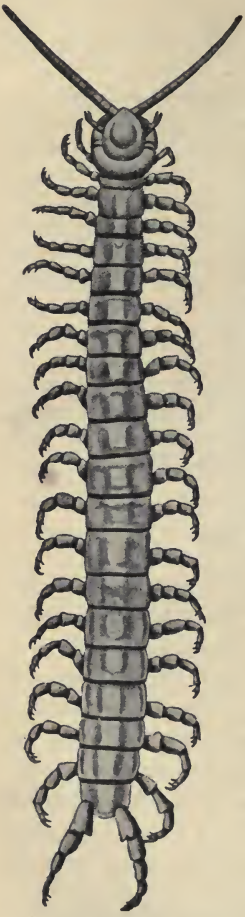

FIG. 140.—**Scolopendra, or centipede.** (From Cuvier's *Animal Kingdom.*)

The number of segments in the body varies from 12 to 173. In the millipedes (*Diplopoda*) the dorsal walls of the segments are very strongly arched; in the centipedes (*Chilopoda*) the segments are all dorso-ventrally compressed, with distinct tergal and sternal shields (*scuta*) separated laterally by intervals of comparatively soft skin on which the stigmata open. In the centipede each segment bears a pair of jointed legs; of these the most anterior pair is extended forwards to form a pair of poison-fangs, at the extremity of the pointed terminal joint of which opens the duct of a poison gland. In the millipedes each segment behind the fourth or fifth bears two pairs of legs, the four or five most anterior having only one pair each, except one segment which is footless. In most of the millipedes and their allies the appendages of the seventh segment are modified in the male to form copulatory organs.

The enteric canal is straight and is much simpler in character than that of the Insecta. The heart is in the form of a long tube, consisting of as many chambers as there are segments in the body. The breathing organs are air-tubes or tracheæ, resembling those of larval insects, such as caterpillars.

4. THE INSECTA

The class **Insecta**, comprising the cockroaches, grasshoppers, dragon-flies, beetles, butterflies, house-flies, and bees, with their many allies, though it is a very extensive one, including as it does a larger number of species than any of the other classes of the Arthropoda, is yet characterised by a remarkable degree of uniformity, no such extremes of modification occurring as are observable among the Crustacea. The body of an insect, like that of a crustacean, is segmented, and bears a series of pairs of jointed appendages. The surface is covered with a chitinous cuticle, forming an exoskeleton, which is sometimes comparatively thin, sometimes thick and hard. Like the body of the crustacean, that of the insect is divisible into certain *regions*. In the Insecta these regions are quite constant in their disposition, and are always three in number, — *head* in front, *thorax* in the middle, and *abdomen* behind. The head is found, when its development is traced, to be formed by the union with the head-lobe of the embryo of some five segments, but in the adult no trace of segmentation is distinguishable. The thorax always consists of three segments, which are usually firmly united together. The abdomen contains from ten to eleven segments.

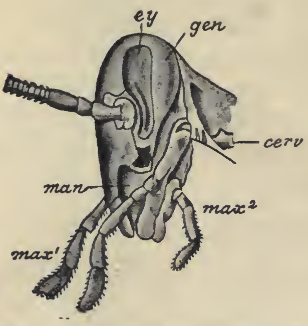

FIG. 141.—**Periplaneta americana.** Lateral view of the head and its appendages. *cerv*, one of the cervical sclerites; *ey*, eye; *gen*, gena; *man*, mandible; *max*^{1}, first pair of maxillæ; *max*^{2}, second pair of maxillæ (labium).

The appendages are also very constant in their arrangement throughout the Insecta, though variously modified in form in the different orders, in accordance with differences in mode of life. The head (Fig. 141) bears a pair of antennæ, a pair of mandibles, and two pairs of maxillæ. The antennæ vary a good deal in size and shape in different insects. The mandibles (Fig. 142, *md*) lie at the sides of the mouth, in front of which is a movable labrum or upper lip (*lbr*). Each mandible is a single solid piece, and is devoid of palp. The second pair of maxillæ (*mx.* 2) are united in their basal portions to form a lower lip (*labium*). Jointed palpi (*pm*) are borne both by the first pair of maxillæ (*maxillary palpi*) and by the second (*labial palpi*). All the jaws become differently modified in the different orders in accordance with differences in the nature of the food. Insects, which like cockroaches and beetles, masticate hard substances, have the mandibles strong and sharp and the maxillæ well developed, and adapted to act as masticatory organs. Insects which, like cicadas, bugs, lice, and plant-lice, live on the juices of plants or animals, have the jaws in the form of sharp stylets, enclosed in a sheath or proboscis, for piercing the integument. Intermediate conditions also occur. In the Hymenoptera (bees, wasps, etc.), for example, the mouth-parts are adapted both for biting and for licking and sucking; the mandibles and maxillæ are sharp and lancet-like, the middle part of the labium is produced into a long median tongue, at the sides of which are a pair of accessory tongues (*paraglossæ*). In the Hemiptera (bugs, lice, etc.) the labium is modified to form a sucking proboscis enclosing the stylet-like mandibles and maxillæ.

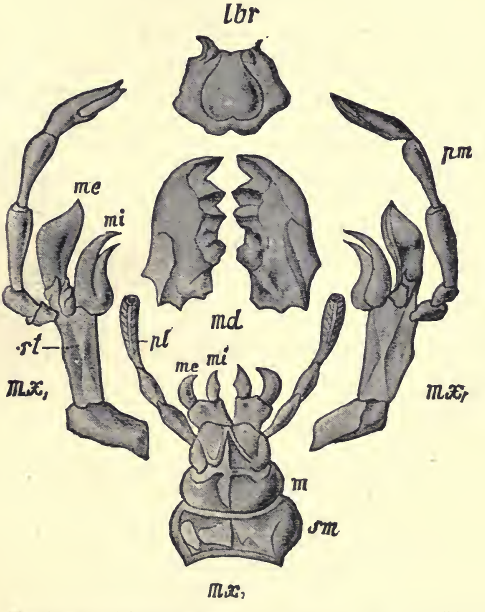

FIG. 142. — Mouth-parts of the **Cockroach**. *lbr*, labrum; *md*, mandible; mx_1, anterior pair of maxillæ; *m*, mentum; *me* and *mi*, outer and inner divisions of the second pair of maxillæ; *pl*, labial palp; *pm*, maxillary palp; *st*, stipes; *sm*, submentum. (From Lang's *Comparative Anatomy*.)

In the Diptera (house-flies, gnats, etc.) the mandibles, usually not developed in the males, are biting or piercing organs, while the basal parts of the labium form a proboscis enclosing a sharp spine developed from a process on the roof of the mouth (*hypopharynx*).

In the Lepidoptera, or butterflies and moths, the mandibles are aborted in the adult and the maxillæ are developed into elongated half-tubes, which are united and form a complete tube capable of being coiled up in a spiral manner under the head, the extremity in some cases being provided with hooks or spines for rupturing the nectaries of flowers.

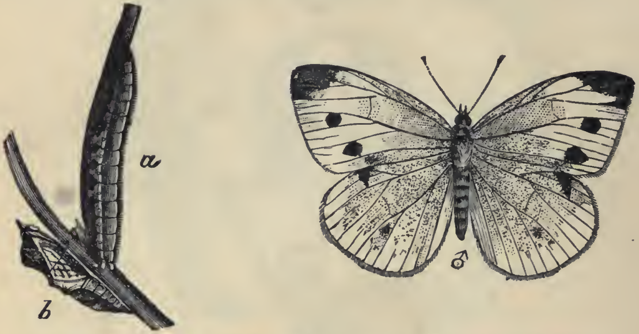

FIG. 143. — Butterfly (**Pieris rapæ**), with caterpillar and chrysalis stages. (After Riley.)

Each of the three segments of the thorax always bears a pair of jointed legs which do not present such marked modifications as the appendages of the head. The terminal part (*tarsus*) is made up of a number (not more than five) of short segments, and ends in a pair of claws, often with an adhesive pad or sucking disc between them.

In addition to the legs, the second and third segments of the thorax usually bear each a pair of *wings*. The wings are thin transparent expansions of the integument supported by a system of branching ribs, called *veins*, or *ner-*

vures. In most of the butterflies and moths (Fig. 143) the wings are opaque, owing to their being covered with numerous overlapping microscopic scales to which the various colours of the wing are due. In the beetles (Fig. 144), locusts, and others, on the other hand, the posterior wings alone are membranous, the anterior pair being converted into hard and tough cases — the *elytra* — which, when folded up, cover over and protect the delicate posterior wings. In the bugs and their allies, the anterior wings are thick and opaque at the bases only. In the house-flies, gnats (Fig. 145), and their allies (order *Diptera*), the anterior wings alone are developed, the posterior being represented by vestiges, the *halteres* or balancers. In the bee-parasites the *posterior* pair of wings are alone developed, the anterior pair being vestigial. In some insects (springtails, lice, fleas) wings are entirely absent in all stages. In others again, as certain moths, they are present in one sex — usually the male — and absent in the other.

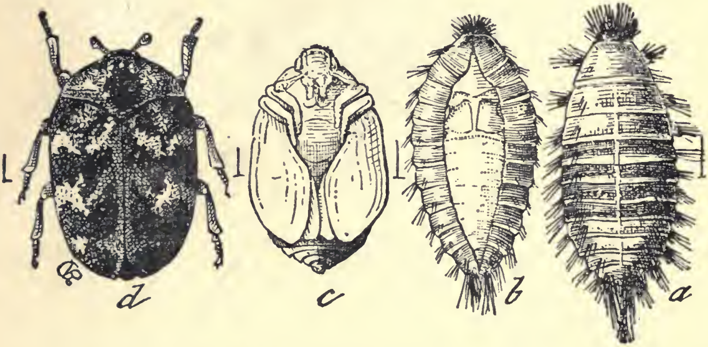

FIG. 144. — *d*, Carpet beetle (**Anthrenus scrophulariæ**) with larva *a*, *b*, and pupa, *c*. (After Riley, from Bulletin of Division of Entomology, United States Department of Agriculture.)

The abdomen is devoid in the adult, except at the posterior extremity, of any paired limbs. At the posterior end there are frequently appendages forming the sting, ovipositor and genital processes, which may be of the nature of modified limbs.

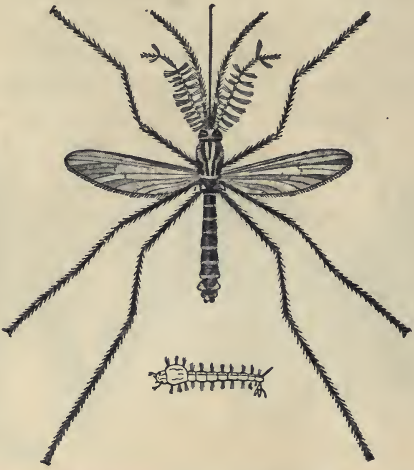

FIG. 145.—**Culex**, mosquito, and larva. (After Guèrin and Percheron.)

The digestive canal (Fig. 146) consists of a number of parts. It is nearly always considerably longer than the body, and is longer in vegetable-feeding than in carnivorous forms. The mouth leads into a buccal cavity into which the ducts of a pair of large salivary glands open.

Following upon this is a narrow *œsophagus* (*œs*), which dilates behind into a *crop* (*cr*) for the storage of food. The place of the crop in sucking insects is taken by a stalked sac, usually termed the *sucking stomach*, but which is more properly a food reservoir. The essential processes of digestion are carried on in an elongated chamber with glandular walls, the *chyle stomach*, which may be divided into several parts. Sometimes there is intercalated between the crop and chyle stomach a muscular chamber frequently containing chitinous teeth, the *gizzard* (*giz*), or *proventricu-*

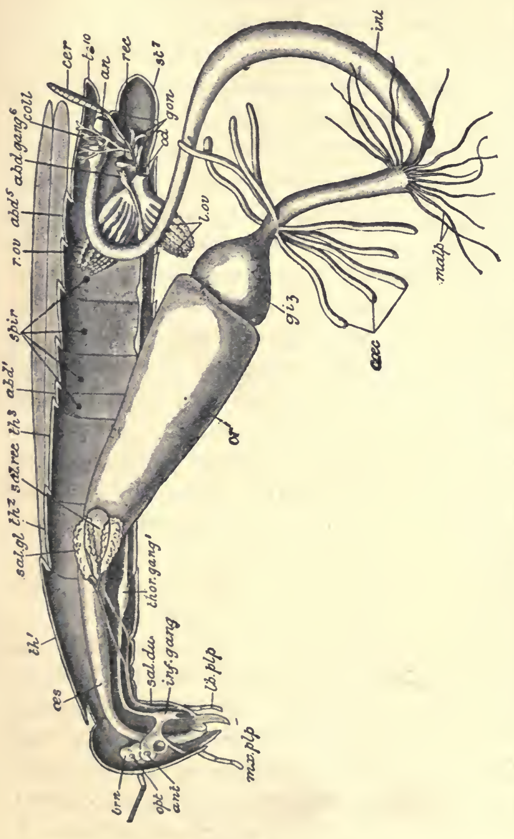
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FIG. 146. — Semi-diagrammatic view of the internal organs of a female **Cockroach**, dissected from the left side. The heart is not represented. *abd^1*, *$abd.^5$* first and fifth abdominal segments; *an*, anus; *ant*, antennary nerve; *brn*, brain; *cer*, anal cercus; *cæc*, cæca; *coll*, collateral glands; *cr*, crop; *gizz*, gizzard; *gon*, gonapophyses; *infr. gang*, sub-œsophageal ganglion; *int*, intestine; *lb. plp*, labial palp; *l.ov*, left ovary; *malp*, malpighian tubes; *mx. plp*, maxillary palp; *od*, points to the external opening of the median oviduct (vagina); *œs.* œsophagus; *r. ov*, right ovary; *sal. gl*, salivary glands; *sal. rec*, salivary receptacle (left); *sal. du*, salivary ducts, indicating the point at which the median duct of the salivary glands unites with the median duct of the salivary receptacles; *spir*, spiracles; *st^7*, sternum of the seventh segment; *te^{10}*, tergum of the tenth segment; *th^1*, *th^2*, *th^3*, first, second, and third segments of the thorax.

lus. Appended to the chyle stomach at its anterior end are in many insects a number of tubular pouches, the *hepatic cœca* (*cœc*). At the junction of the chyle stomach with the small intestine, or further back, there open a number (from 2 to over 100) of narrow tubular appendages, the Malpighian tubes (*malp*), which are the organs of renal excretion. The intestine is usually elongated, its posterior portion is dilated to form a wide rectum, which opens in the anal aperture on the last segment. Anal glands producing an odoriferous secretion often open into the rectum.

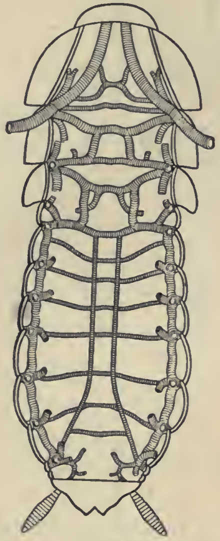

FIG. 147.— **Periplaneta.** View of the arrangement of the principal trunks of the tracheal system. (After Miall and Denny.)

The organs of respiration are a system of fine branching tubes, the *tracheæ* (Fig. 147), which communicate with the exterior through valvular apertures known as *stigmata* situated at the sides of the segments. These tracheæ form a completely ramifying system which conveys the air to all the parts of the body. The wall of the tubes is strengthened by a series of spirally wound chitinous fibres, each fibre or thread making from one to four or five turns around the tracheæ. In some insects, mainly those adapted for active flight, the tracheal system is dilated in certain parts of the body to form large *air sacs*. In the aquatic larvæ of some insects there is a series of soft external simple or divided processes — the *tracheal gills* — attached to the abdominal segments, and richly supplied with tracheæ which have no communication with the exterior.

The blood-vascular system is, in comparison with the other systems of organs, not very highly developed, the need of an elaborate system of vessels being greatly diminished by the thorough way in which all the organs are supplied with oxygen by means of the tracheæ. The blood is colourless, or faintly yellowish or greenish. A contractile tubular heart divided internally into a row of eight chambers by a system of valves extends through the abdomen on the dorsal aspect.

The nervous system (Fig. 148) is on the same general plan as in the Crustacea. There is a double supra-œsophageal ganglion or brain (*br*), a sub-œsophageal ganglion (*inf*), also double, and a series of thoracic and abdominal pairs of ganglia, which are closely united together in the middle line. The brain is relatively large in the higher insects, and is divided into several lobes. It gives off nerves to the antennæ and ocelli and the labrum, and on each side it gives off a large lobe, the *optic ganglion*, on which the compound eye rests. A pair of *œsophageal connectives* (*conn*) pass backwards on either side of the mouth from the brain to the sub-œsophageal ganglia. These connectives are very short, and, as a consequence, the brain and sub-œsophageal

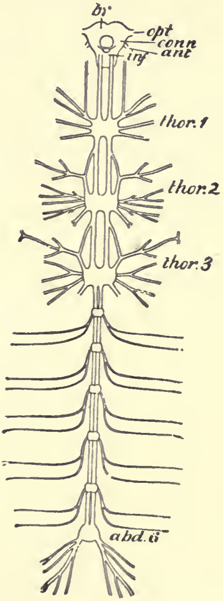

Fig. 148. — **Periplaneta.** General view of the nervous system. *abd. 6*, sixth abdominal ganglion; *ant*, antennary nerve; *br*, brain; *conn*, œsophageal connective; *inf*, sub-œsophageal ganglion; *opt*, optic nerve: *thor. 1*, *thor. 2*, *thor. 3*, first, second, and third thoracic ganglia. (After Miall and Denny.)

ganglia are closely approximated. There are sometimes three pairs of thoracic and as many as eight of abdominal ganglia in the adult insect, but in many there is a greater or less degree of concentration of the ventral ganglionic chain.

The most highly developed organs of special sense are the large compound eyes which are situated on the sides of the head. The surface of the compound eye is marked out, as in the case of the crayfish, into a great number of minute hexagonal facets, each of which corresponds to one of the elements (*ommatidia*) of which the eye is made up. In addition to the large compound eyes most insects have simple unfaceted eyes or *ocelli*. In a few insects eyes are entirely wanting.

The antennæ and palpi are the organs of touch, and these appendages seem also to be the seat of the olfactory sense. The sense of taste is probably also developed in some insects in minute papillæ on the *epipharynx* which forms the roof of the mouth and also at the base of the maxillæ. Special nerve-endings supposed to be auditory occur in various parts of the body in some cases.

The sexes are always separate, and the males and females are very commonly distinguishable from one another by various modifications of form and of coloration. Some insects, such as the Aphides and bees and wasps, present us with the unusual phenomenon of parthenogenesis, *i.e.*, ova are formed, as in ordinary female insects, in organs corresponding to the ovary of the latter, and these are developed without fertilisation. In the case of the Aphides, an autumn generation of completely developed males and females is followed by a spring generation consisting entirely of females; these are both parthenogenetic and viviparous. In the bees the workers (imperfectly developed females) occasionally produce ova which, without fertilisation, develop into males (drones). In one or two groups, including the scale insects (*Coccidæ*), and gall insects (*Cynipidæ*), males are never developed, so that reproduction is exclusively parthenogenetic. *Pædogenesis* accompanies parthenogenesis in certain of the Diptera or two-winged insects, *i.e.*, the larva produces ova and embryo without impregnation.

The eggs when laid are protected from injury by a number of methods: they may be buried in the earth, or laid in the interior of certain plants or even animals. The deposition of eggs by means of an ovipositor in the leaves or other parts of plants gives rise to swellings —*galls*— in the interior of which the young insects are protected and nourished. In the case of many insects the eggs are enclosed in a cocoon; in others they are enclosed in gelatinous or waxy material.

In some instances the young insect, when it escapes from the egg, has exactly the form of the parent, except that perhaps the wings have not yet grown. But in most instances there is a metamorphosis. In some this is comparatively slight and gradual, the adult insect differing from the larva only in comparatively unimportant points, and the segments and appendages of the latter becoming directly converted into those of the former. Such a metamorphosis is said to be *incomplete*. The term *complete* is applied to the metamorphosis of the majority of insects, in which the larva differs so completely from the *imago*, or perfect insect, in external form, the nature of the appendages and the internal organisation, that there is need of a quiescent or *pupa* stage during which the whole animal, or a considerable part of it, undergoes an entire transformation. The butterflies and moths (*Lepidoptera*) (Fig. 143) may be taken as a good example of such a complete metamorphosis. The larvæ, or caterpillars, are worm-like, but with well-developed jaws, three pairs of jointed thoracic legs, and a number of unjointed stumpy abdominal legs. Eventually the caterpillar spins a cocoon of a silky substance, enclosed within which, and covered with a tough skin, it passes through a quiescent or *pupa* condition — the condition of the *chrysalis*. From the interior of this the imago subsequently emerges with all the parts of the adult insect fully formed.

In *mode of life* there is a very considerable difference between different orders and families of insects. Some are parasites in the strict sense throughout life. This is the case, for instance, in the Strepsiptera (bee-parasites), the females of which live permanently ensconced between the joints of the abdomen of their hosts. The lice and bird-lice are external parasites throughout life; bugs and fleas, though not adhering to their hosts, are parasites as regards their diet. Many insects are parasites in the larval condition, though free in the adult state. This holds good, for example, of the larvæ of the ichneumons, which develop in the interior of the bodies of other insect-larvæ, also of the larvæ of the bot-flies, which inhabit the alimentary canal of mammalian hosts (horses, oxen, sheep, rhinoceroses, tapirs).

In accordance with the high grade of the structure of their various systems of organs, insects exhibit a correspondingly high degree of functional activity. The quantity of food consumed and assimilated is great in comparison with the bulk of the body, and the energy expended in muscular contractions is of very considerable amount. It is estimated that while the muscular force exerted by a horse bears a ratio of about 0.7 to its own weight (reckoned as 1), the muscular force of an insect bears a ratio to its weight of from about 14 to about 23. Insects are also distinguished among the Invertebrata by the keenness of their senses. The sense of sight is, as we should expect from the elaborate character of the optic organs, the most highly developed, many insects having been shown by experiment to have a keen sense of colour; but a sense of smell, the seat of which is in the antennæ, can be shown to exist in a high degree, and the parts about the mouth bear nerve-endings concerned in a well-developed sense of taste. A sense of hearing does not appear to be universally present, but is well marked in such forms as produce sounds. At the same time insects are remarkable for the instincts, often leading to results of an elaborate character, which guide them in the pursuit of food and the protection and rearing of their young. Among the insects which are the most highly endowed in this respect are some — the ants, bees, wasps, and termites — which live together in organised associations or communities, the various individuals composing which are distinguishable into *sexual individuals*, *neuter workers*, and *soldiers* (Figs. 149 and 150),

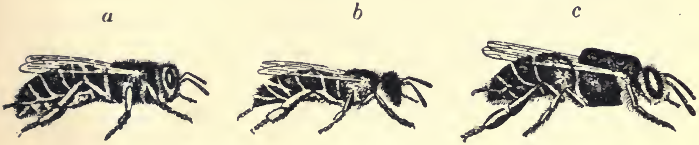

FIG. 149. — Honey bee (**Apis mellifica**). *a*, queen (perfect female); *b*, worker (imperfect female); and *c*, drone (male). (After Brehm.)

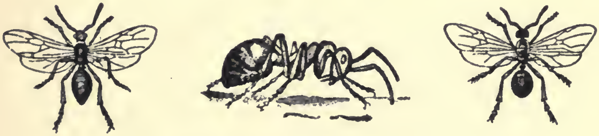

FIG. 150. — Red ant (**Formica rufa**). Male, worker, and female.

each specially organised for the part which it has to play in the economy of the community.

5. THE ARACHNIDA

The **Arachnida**, comprising the scorpions and spiders, the mites and ticks, the king-crabs, and a number of other families, is a much less homogeneous group than the Insecta, approaching the Crustacea in the variety which it presents in the arrangement of the segments and their appendages. In most members of the class, however, there is an anterior region of the body — the *cephalothorax* — representing both head and thorax, and a posterior part or *abdomen*, which is typically composed of a number of distinct segments; in some cases cephalothorax and abdomen are united.

Scorpions are inhabitants of warm countries, the largest kinds being found in tropical Africa and America. They are nocturnal animals, remaining under stones or in holes and crevices during the day, and issuing forth at night to hunt for their prey, which consists of spiders and insects. These they seize with their pincer-claws and sting to death with their caudal spine, afterwards sucking their juices.

There are a number of different species of scorpions, divided into several genera, which differ from one another in comparatively unimportant points, so that the following general description will apply almost equally well to any of them.

A scorpion (Fig. 151) has a long narrow body, in superficial appearance not unlike that of a crayfish. There is a small cephalothoracic shield or *carapace*, covering over dorsally a short anterior region or *cephalothorax*. This is followed by a long posterior region or *abdomen*, the terminal part of which in the living animal is habitually carried over the back (Fig. 151), constituting the "tail," at the end of which the sting is placed. The carapace bears a pair of large eyes about its middle, and several pairs of smaller eyes on the antero-lateral margin. The anterior, broader part of the abdomen, which is termed the *præ-abdomen*, consists of seven segments, each of which is protected by firm, chitinous, dorsal, and ventral plates, or *terga* and *sterna*. The tergum and sternum of each segment are separated from one another laterally by intervals of soft skin, except in the seventh, where they are united laterally for a longer or shorter distance. The posterior, narrower part of the abdomen, known as the *post-abdomen*, consists of five segments, each enclosed in a complete investing ring of hard chitinous matter. Articulating with the last segment of the post-abdomen is a terminal appendage, the caudal spine or *sting*, swollen at the base and acutely pointed at the apex, where open the ducts of two *poison glands*. The *anal opening* is situated on the ventral surface of the last segment of the post-abdomen, immediately in front of the sting.

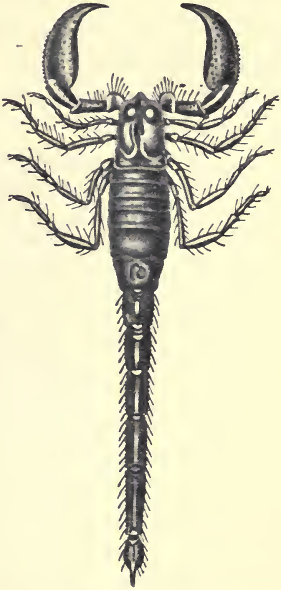

Fig. 151.—**Euscorpio.** (From Cuvier's *Animal Kingdom*.)

The aperture of the *mouth*, which is very small, is at the anterior end of the cephalothorax on its ventral aspect; a lobe which overhangs it in front is the *labrum*. On each side of the mouth is a three-jointed appendage — the *chelicera* (Fig. 152, *chel*) — which is terminated by a chela. Behind these are the very large *pincer-claws*, or *pedipalpi* (*ped*), each composed of six podomeres and terminating in powerful chelæ. The basal joint of each pedipalp has a process which bites against the corresponding process of the other pedipalp, these processes thus performing the functions of jaws. Following upon the pedipalpi are four pairs of walking legs, each composed of seven podomeres, the last of which is provided with a pair of small curved and pointed

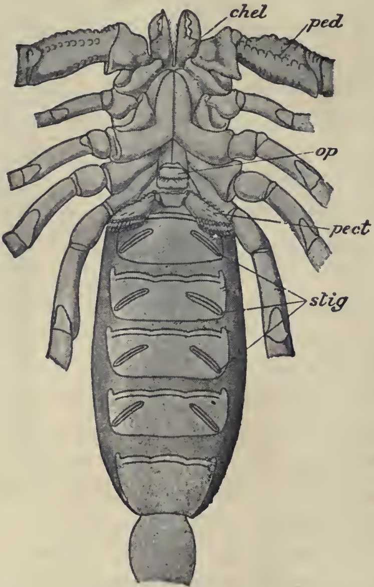

FIG. 152. — **Scorpion.** Ventral surface of the cephalothorax and præ-abdomen. *chel*, cheliceræ; *op*, operculum; *pect*, pectines; *ped*, pedipalpi; *stig*, stigmata.

horny claws. The basal segments of the first two pairs of walking legs are modified so as to perform to some extent the function of jaws.

All the six pairs of appendages hitherto described — the cheliceræ, the pedipalpi, and the four pairs of walking legs — belong to the cephalothorax. The first segment of the præ-abdomen (Fig. 152) has a narrow sternum, on which there is placed a soft rounded median lobe divided by a cleft; this is termed the *genital operculum* (*op.*); at its base is the opening of the genital duct. To the sternum of the second segment of the præ-abdomen are attached a pair of remarkable appendages of a comb-like shape, — the *pectines* (*pect*), — each consisting of a stem, along the posterior margin of which is a row of narrow processes, somewhat like the teeth of a comb; the function of these appendages is doubtful, but is probably sensory. The remainder of the segments of the præ-abdomen, and all those of the post-abdomen, are devoid of appendages. The sterna of the third, fourth, fifth, and sixth segments of the præ-abdomen, which are very broad, bear each a pair of oblique slits — the *stigmata* (*stig*) — leading into the pulmonary sacs.

All the appendages of the scorpion are post-oral in position, and the most anterior — the chelicerae — are probably best regarded as corresponding to the antennæ of the crayfish, the equivalent of the crayfish's antennules and of the antennæ of the cockroach not being present. The pedipalpi would then be the homologues of the mandibles of the insect and the crustacean.

The *organs of respiration* in the scorpions are in the form of *pulmonary sacs* or *book-lungs* (Fig. 153, *pul*), the stigmata or external openings of which have already been referred to. Each pulmonary sac is a compressed chamber lined with a thin cuticle. The lining membrane is raised

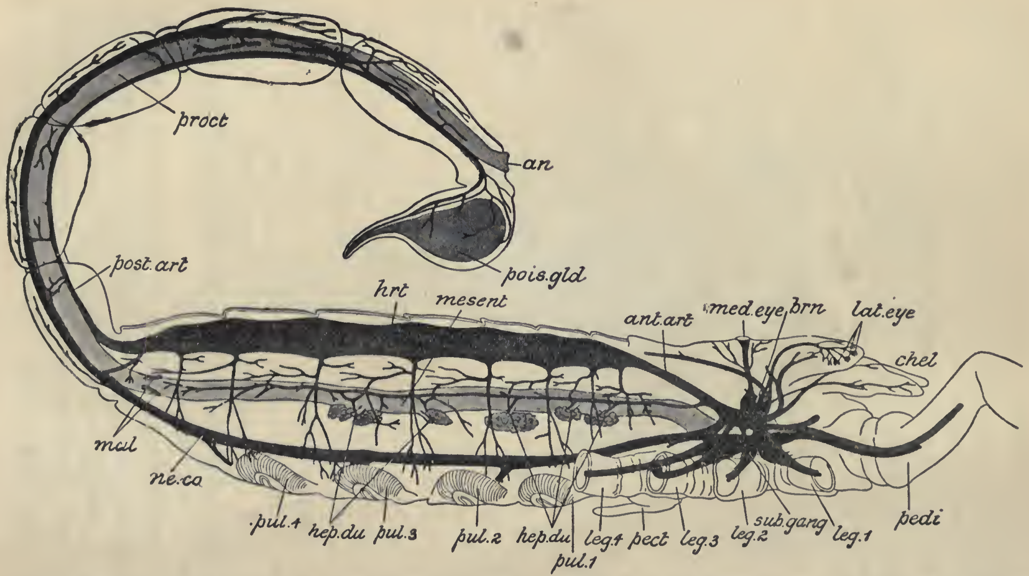
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Fig. 153. — Diagrammatic side view of the internal organs of **Scorpion.** *an*, anus; *ant. art*, anterior aorta; *brn*, brain; *chel*, cheliceræ; *hep. du*, hepatic duct; *hrt*, heart; *lat. eye*, lateral eyes; *leg*, *1–4*, legs; *mal*, Malpighian tubes; *med. eye*, median eye; *mesent*, mesenteron; *ne. co*, nerve cord; *pect*, pectines; *ped*, pedipalp; *pois. gld*, poison gland; *post. art*, posterior aorta; *proct*, proctodæum; *pul*, *1–4*, pulmonary sacs; *sub. gang*, sub-œsophageal ganglion. (From Leuckart, after Newport and Blanchard.)

up into numerous delicate laminæ lying parallel with one another, like the leaves of a book. Into the numerous narrow spaces between the laminæ the air penetrates, and oxygenates the blood which enters the interior of the laminæ from the ventral blood-sinus. In the United States the common scorpion from Florida to North Carolina is *Buthus carolinianus;* other species occur in Utah, New Mexico, etc., and in Southern California.

The **Spiders** (Fig. 154) differ from the scorpions in having the abdomen short, rounded, and unsegmented, in having the cheliceræ subchelate and provided with poison glands, the ducts of which open at their extremities, and the pedipalpi simple, the terminal joint in the male being expanded, and the whole appendage being used as an intromittent organ for the transference of the sperm to the genital opening of the female. At the extremity of the abdomen is a peculiar apparatus, the *arachnidium* or spinning organ. This consists of four or six appendages, the *spinnerets*, on the surfaces of which open the numerous ducts of the spinning glands secreting the material of which the web is composed. The fine threads of viscid secretion issuing from the ducts harden on exposure to the air, and are worked up into the web by means of the posterior legs. There are six or eight eyes on the carapace. The organs of respiration are either four pulmonary sacs similar to those of the scorpion, or two pulmonary sacs, and a system of tracheæ resembling those of insects.

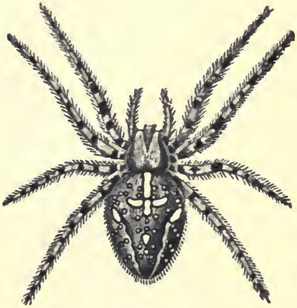

Fig. 154. — Spider (**Epeira diadema**).

In the **Mites** and **Ticks** (Fig. 155) no distinction into regions is recognisable, but there are the same series of paired appendages as in the scorpions and spiders. The cheliceræ and pedipalpi, and also the legs, differ somewhat in form in different groups, in accordance with differences in mode of life. Organs of respiration, when present, take the form of tracheæ. The cattle tick, *Ixodes bovis*, is the medium of conveyance of the Texas cattle disease.

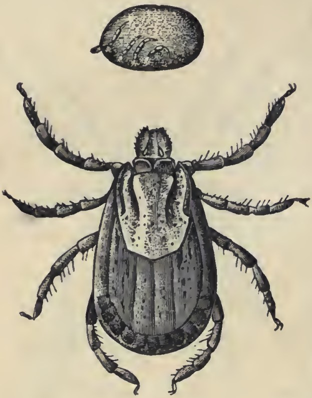

FIG. 155. — Cattle Tick. Above, nat. size, side view; below, dorsal view, enlarged. (From Packard.)

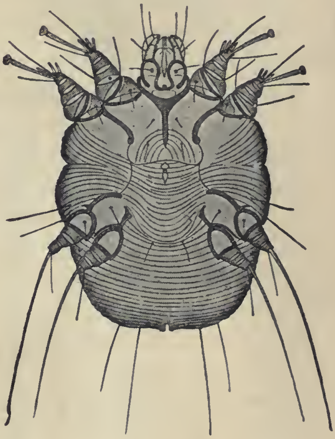

FIG. 156. — Itch mite (**Sarcoptes scabiæi**). (After Leuckart.)

The **Xiphosura** or **King-crabs**, an order comprising the single genus *Limulus*, differ widely from the scorpions and spiders.[1] Limulus (Fig. 157) is a marine arthropod breath-

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[1] The Xiphosura, with their fossil allies, the Eurypterida, are by some authors regarded as forming a distinct class, by others they are included among the crustacea. It seems better to refer them to a distinct class, the *Merostomata*. — AMERICAN EDITOR.

ing by gills, in which the body consists of two regions, — the cephalothorax and the abdomen. The former is covered over by a broad shield or carapace, bearing two large compound and two smaller, simple eyes. The segments of the

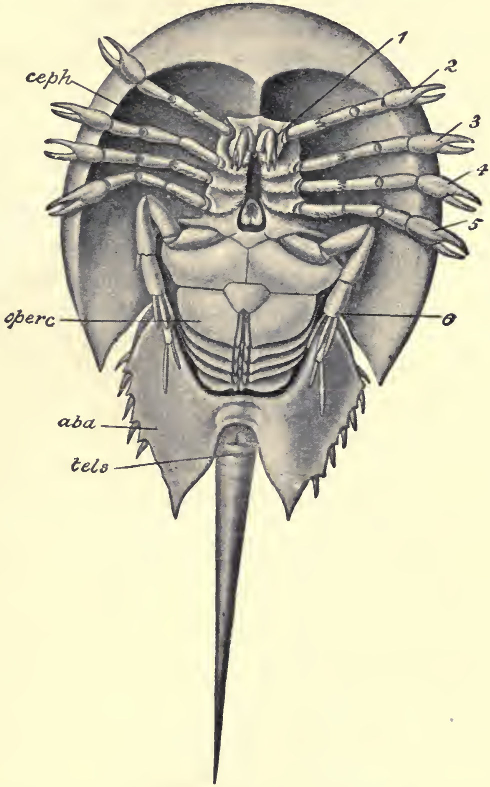

FIG. 157. — Ventral view of **Limulus**. *1–6*, appendages of cephalothorax; *abd*, abdomen; *ceph*, cephalothorax; *operc*, operculum, behind which are seen the series of abdominal appendages; *tels*, caudal spine or telson. (From Packard, after Kingsley.)

abdomen (nine in number) are united together, being covered dorsally by a continuous abdominal carapace. At the posterior end is attached a very long, narrow, *caudal spine* which is a modification of the ninth abdominal segment of the larva. The anterior appendages (Fig. 157) somewhat resemble those of the scorpion. In front of the mouth is a pair of short, three-jointed, chelate appendages, the *chelicerœ*, at the sides of a labrum or upper lip. Behind these follow a series of five pairs of legs, the bases of all of which, with the exception of the last, are covered with spines, and have the action of jaws, while the extremities are for the most part chelate. The first pair of appendages of the abdomen are flat plates, which are united together in the middle line and together form the broad *operculum* (*operc*), overlapping all the posterior appendages; on its posterior face are the two genital apertures. The posterior appendages, of which there are five pairs, are thin, flat plates to which the gills are attached; each of them is divided by sutures into a small inner ramus or endopodite, and a larger external ramus or exopodite. A labrum (*rostrum*) lies in front of the mouth, and between the sixth pair of appendages is a pair of processes, the *chilaria*.

In their mode of life the Arachnida present almost as great a diversity as the Insecta. Some Acarida are parasites throughout life. Most of the other groups of Arachnida are predaceous, preying for the most part on insects or other arachnids. To capture the insects which constitute their food, the majority of spiders construct a web formed of the threads secreted by the arachnidium. The primary function of the threads formed from the secretion of the spinning organ is to constitute the material for the manufacture of a cocoon for enclosing the eggs, and in some arachnids this is the sole purpose to which they are devoted. In others there is added a nest for the protection of the eggs and of the parent itself; this in many cases becomes a permanent lurking place which the spider inhabits at all seasons, and from which it darts out to capture its prey; in the trap-door spider the nest has a closely fitting hinged lid. In very many spiders the secretion is used mainly to form the web by means of which the prey is snared, with the addition frequently of a nest in which the spider lies in wait. A subsidiary function of the threads is to aid in locomotion, the spider being enabled by means of them to let itself down safely from considerable heights, and even to float in the air.

Some of the mites, as already mentioned, are parasitic; others feed on various kinds of fresh or decaying animal or vegetable substances. Most free Acarida are terrestrial, some are aquatic.

The Xiphosura are marine, living from low-water mark to the depth of a few fathoms in warm seas, burrowing in sand; their food consists of various kinds of marine annelids. *Limulus polyphemus* inhabits our coast from Florida to, and just east of the mouth of, the Kennebec River, Maine.

SECTION XI.—PHYLUM MOLLUSCA

GROUPED together in the Phylum **Mollusca** are a large assemblage of animals exhibiting as great a diversity in their structure as is observable among the Arthropoda. The animals popularly known as "shell-fish," such as the mussels, oysters, and scallops, the whelks, limpets, and snails, together with the cuttle-fishes and many others, are comprehended within this extensive phylum. If we compare a mussel, a whelk, and a cuttle-fish, we may experience a difficulty in finding a sufficient number of features common to all three to justify us placing them together in one phylum. They are all unsegmented, and are devoid of the continuous enclosing crust and the jointed appendages of the Arthropoda; and they all possess, in different forms, a calcareous shell, with, in relation to it, a specially modified area of the skin, the *mantle*; but it is only on a careful analysis and comparison of the various parts that we are enabled to arrive definitely at the conclusion that they all present us with modifications of the same general plan of structure.

Five classes are comprised in the phylum; (1) the **Pelecypoda**, or bivalved shell-fish, such as mussels, cockles, oysters, scallops, etc.; (2) the **Amphineura**; (3) the **Gastropoda**, including the univalved shell-fish, such as periwinkles, whelks, snails, slugs, etc.; (4) the **Scaphopoda** or elephant's tusk shells;[1] and (5) the **Cephalopoda**, including the cuttle-fishes, squids, octopi, and nautili.

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[1] Not further referred to in this work.

1. THE PELECYPODA

A **Fresh-water Mussel** will serve as a convenient example of the Pelecypoda.[1] Fresh-water mussels are found in rivers and lakes in most parts of the world. *Anodonta cygnea*, the swan-mussel, is the commonest species in England; but the pearl-mussel, *Unio margaritifer*, is found in mountain streams, and other species of the same genus are universally distributed. *Unio complanatus* is the common fresh-water pearl-mussel in the Eastern United States, and *Anodonta fluviatilis* represents the European *A. cygnea*.

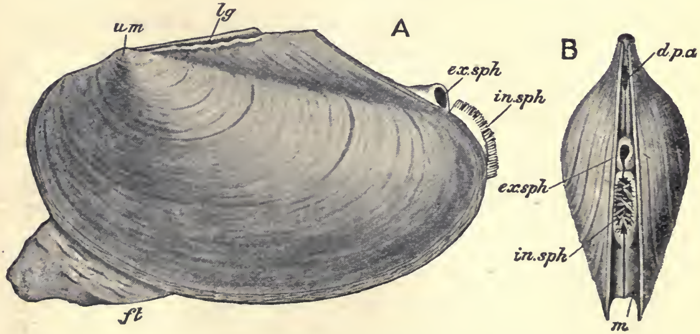

FIG. 158. — **Anodonta cygnea.** The entire animal. A, from the left side; B, from the posterior end. *d. p. a*, dorsal pallial aperture; *ex. sph*, exhalant siphon; *ft*, foot; *in. sph*, inhalant siphon; *lg*, ligament; *m*, mantle; *um*, umbo. (After Howes.)

The mussel (Fig. 158) is enclosed in a brown shell formed of two separate halves or *valves* hinged together along one edge. It lies on the bottom, partly buried in the mud or sand, with the valves slightly gaping, and in the narrow cleft thus formed a delicate, semi-transparent substance (*m*) is seen, the edge of the *mantle* or *pallium*. The mantle really consists of separate halves or *lobes* corresponding with the valves of the shell, but in the position of rest the two lobes are so closely approximated as to appear simply like a membrane uniting the valves. At one end, however, the mantle projects between the valves in the form of two short tubes, one (*ex. sph*) smooth-walled, the other (*in. sph*) beset with delicate processes or *fimbriæ*. By diffusing particles of carmine or indigo in the water it can be seen that a current is always passing in at the fimbriated tube, hence called the *inhalant siphon*, and out at the smooth or *exhalant siphon*. Frequently a semi-transparent, tongue-like body (*ft*) is protruded between the valves at the opposite side from the hinge, and at the end furthest from the siphons; this is the *foot;* by its means the animal is able slowly to plough its way through sand or mud. When the mussel is irritated, the foot and siphons are withdrawn and the valves tightly closed. In a dead animal, on the other hand, the shell always gapes, and it can then be seen that each valve is lined by the corresponding lobe of the mantle, that the exhalant siphon is formed by the union of the lobes above and below it, and is thus an actual tube; but that the boundary of the inhalant siphon facing the gape of the shell is simply formed by the approximation of the mantle lobes, so that this tube is a temporary one.

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[1] The earlier and quite as appropriate name of this class is *Lamellibranchiata*. — AMERICAN EDITOR.

The hinge of the shell is dorsal, the gape ventral, the end bearing siphons posterior, the end from which the foot is protruded anterior; hence the valves and mantle-lobes are respectively right and left.

In a dead and gaping mussel the general disposition of the parts of the animal is readily seen. The main part of the body lies between the dorsal ends of the valves; it is produced in the middle ventral line into the keel-like foot, and on each side, between the foot and the corresponding mantle-lobe, are two delicate striated plates, the *gills*. Thus the whole animal has been compared to a book, the back being represented by the hinge, the covers by the valves, the fly-leaves by the mantle-lobes, the two first and the two last pages by the gills, and the remainder of the leaves by the foot.

When the body of the mussel is removed from the shell the two valves are seen to be united along a straight *hinge-line* (Fig. 159, A, *h. l*), by a tough, elastic substance, the *hinge-ligament* (Fig. 158, *lg*) passing transversely from valve to valve. It is by the elasticity of this ligament that the shell is opened; it is closed, as we shall see, by muscular action; hence the mere relaxation of the muscles opens the shell. In Anodonta the only junction between the two valves is afforded by the ligament, but in Unio each is produced into strong projections and ridges, the *hinge-teeth*, separated by grooves or sockets, and so arranged that the teeth of one valve fit into the sockets of the other.

The valves are marked externally by a series of concentric lines (Fig. 158) parallel with the free edge or gape, and starting from a swollen knob or elevation, the *umbo* (*um*), situated towards the anterior edge of the hinge-line. These lines are *lines of growth*. The shell is thickest at the umbo, which represents the part first formed in the young animal, and new layers are deposited under this original portion, as secretions from the mantle.

The inner surface of the shell also presents characteristic markings (Fig. 159, A). Parallel with the gape and at a short distance from it is a delicate streak (*pl. l*) caused by the insertion into the shell of muscular fibres from the edge of the mantle; the streak is hence called the *pallial line*. Beneath the anterior end of the hinge the pallial line ends in an oval mark, the *anterior adductor impression* (*a. ad*), into which is inserted one of the muscles which close the shell. A similar but larger *posterior adductor impression* (*p. ad*) lies beneath the posterior end of the hinge.

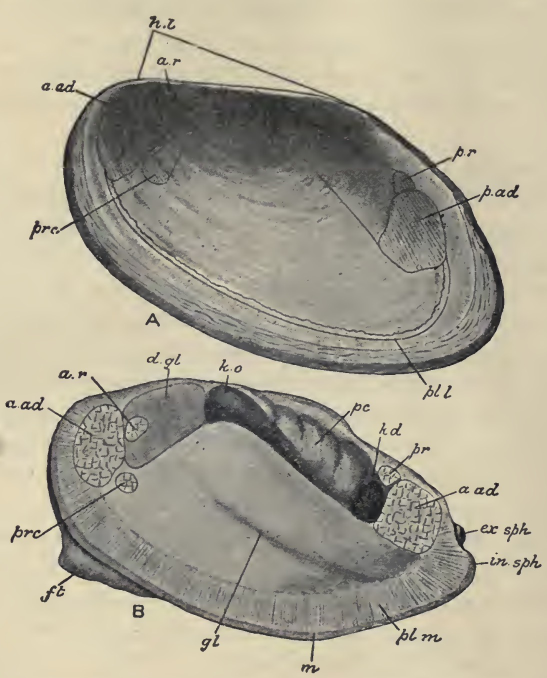

Fig. 159.—**Anodonta cygnea.** A, interior of right valve; B, the animal removed from the shell. *a. ad*, anterior adductor or its impression; *a. r*, anterior retractor or its impression; *d. g*, digestive gland, seen through mantle; *ex. sph*, exhalant siphon; *ft*, foot; *gl*, gills, seen through mantle; *h. l*, hinge-line; *in. sph*, inhalant siphon; *kd*, kidney, seen through mantle; *k. o*, Keber's organ, seen through mantle; *m*, mantle; *p. ad*, posterior adductor or its impression; *pc*, pericardium, seen through mantle; *pl. l*, pallial line; *pl. m*, pallial muscles; *p. r*, posterior retractor or its impression; *prc*, protractor or its impression.

The shell consists of three layers. Outside is a brown horn-like layer, the *periostracum* (Fig. 160, *prs*), composed of *conchiolin*, a substance allied in composition to chitin. Beneath this is a *prismatic layer* (*prc*), formed of minute prisms of calcium carbonate separated by thin layers of conchiolin; and lastly, forming the internal part of the shell, is the *nacre* (*n*) or "mother-of-pearl," formed of alternate layers of carbonate of lime and conchiolin arranged parallel to the surface. The periostracum and the prismatic layer are secreted from the edge of the mantle only, the pearly layer from the whole of its outer surface. The hinge ligament is continuous with the periostracum, and is to be looked upon simply as a median uncalcified portion of the shell, which is therefore, in strictness, a single continuous structure.

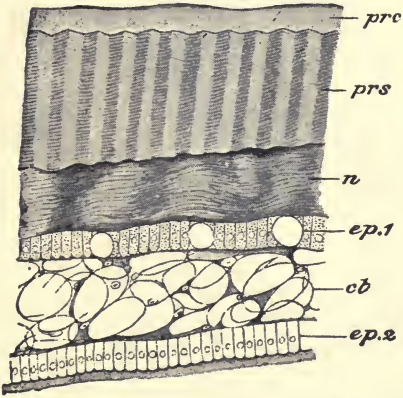

FIG. 160.—Vertical section of shell and mantle of **Anodonta**; *ct*, connective-tissue layer of mantle; *ep.1*, its outer epithelium; *ep.2*, its inner epithelium; *n*, nacreous layer of shell; *prc*, prismatic layer; *prs*, periostracum. (After Claus.)

By the removal of the shell the *body* of the animal (Fig. 159, B) is seen to be elongated from before backwards, narrow from side to side, produced on each side into a mantle-lobe (*m*), and continued ventrally into a keel-like *visceral mass* (Fig. 161, *v. m*), which passes below and in front into the foot (*ft*). Thus each valve of the shell is in contact with the dorso-lateral region of the body of its own side together with the corresponding mantle-lobe, and it is from the epithelium (Fig. 160, *ep.1*) covering these parts that the shell is formed as a cuticular secretion. The whole

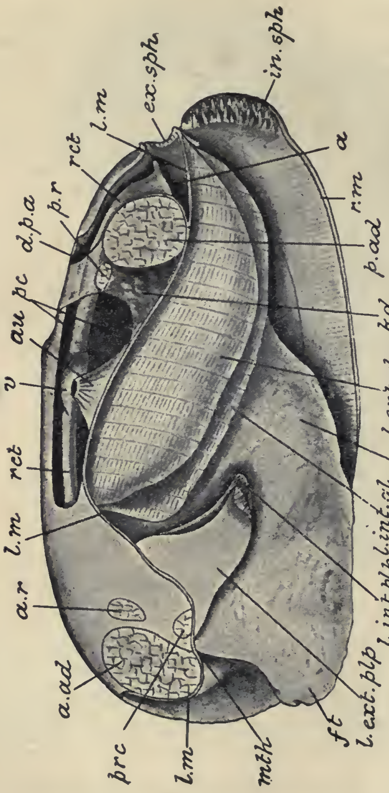

Fig. 161.—**Anodonta cygnea**. The animal with most of the left mantle-lobe removed. *a*, anus; *a. ad*, anterior adductor; *a. r*, anterior retractor; *au*, left auricle; *d. p. a*, dorsal pallial aperture; *ex. sph*, exhalant siphon; *ft*, foot; *in. sph*, inhalant siphon; *kd*, kidney; *l. ext. gl*, left external gill; *l. ext. plp*, left external labial palp; *l. int. gl*, left internal gill; *l. int. plp*, left internal labial palp; *l. m*, cut edge of left mantle-lobe; *mth*, mouth; *p. ad*, posterior adductor; *pc*, pericardium; *p. r*, posterior retractor; *prc*, protractor; *rct*, rectum; *r. m*, right mantle-lobe; *v*, ventricle; *v. m*, visceral mass.

space between the two mantle-lobes, containing the gills, visceral mass, and foot, is called the *mantle-cavity.*

Of the muscles the largest and most important are the *anterior* and *posterior adductors* (Figs. 159 and 161, *a, ad, p. ad*), great cylindrical muscles, passing transversely across the body, and inserted at either end into the valves of the shell, which are approximated by their contraction.

The *cœlom* is reduced to a single ovoidal chamber, the *pericardium* (Fig. 161, *pc*) lying in the dorsal region of the body, and containing the heart and part of the intestine. In the remainder of the body the space between the ectoderm and the viscera is filled by the muscles and connective tissue.

The *mouth* (Fig. 161, *mth*) lies in the middle line just below the anterior adductor. On each side of it are two triangular flaps, the *internal* (*l. int. plp*) and *external* (*l. ext. plp*) *labial palps;* both are ciliated externally. The mouth leads by a short *gullet* (Fig. 162, *gul*) into a large *stomach* (*st*), which receives the ducts of a pair of irregular, dark-brown, *digestive glands* (*d. gl*). The *intestine* (*int*) is given off from the posterior end of the stomach, descends into the visceral mass where it is coiled upon itself, then ascends parallel to its first portion, turns sharply backwards, and proceeds, as the *rectum* (*rct*), through the pericardium, where it traverses the ventricle of the heart, and above the posterior adductor, finally discharging by the *anus* (*a*) into the exhalant siphon or cloaca. The stomach contains, at certain seasons of the year, a gelatinous rod, the *crystalline style.*

The **gills** consist, as we have seen, of two plate-like bodies on each side between the visceral mass and the mantle; we have thus a *right* and a *left outer* (Fig. 161, *l. ext. gl*) and a *right* and a *left inner gill* (*l. int. gl*). Seen from the surface each gill presents a delicate double striation, being marked by faint lines running parallel with, and by more pronounced lines running at right angles to, the long axis of the organ. Moreover, each gill is double, being formed of two similar plates, the *inner* and *outer lamellæ*, uniting with one another along the interior, ventral, and posterior edges of the gill, but free dorsally. The gill has thus the form of a long and extremely narrow bag open above (Figs. 162 and 163) ; its cavity is subdivided by vertical bars of tissue, the *inter-lamellar junctions* (*i. l. j.*), which extend between the two lamellæ, and divide the intervening space into distinct compartments or *water tubes* (*w. t*) closed ventrally, but freely open along the dorsal edge of the gill. The vertical striation of the gill is due to the fact that each lamella is made up of a number of close-set *gill-filaments* (*f*) ; the longitudinal striation to the circumstance that these filaments are connected by horizontal bars, the *inter-filamental junctions* (*i. f. j*). At the thin, free, or ventral edge of the gill the filaments of the two lamellæ are continuous with one another, so that each gill has actually a single set of V-shaped filaments, the outer limbs of which go to form the outer lamella, their inner limbs the inner lamella. Between the filaments, and bounded above and below by the inter-filamental junctions, are minute apertures, or *ostia* (*os*), which lead from the mantle-cavity through a more or less irregular series of cavities into the interior of the water tubes. The filaments themselves are supported by chitinous rods (*r*), and are covered with ciliated epithelium, the large cilia of which produce a current running from the exterior through the ostia into the water tubes, and finally escaping by the wide dorsal apertures of the latter. The whole organ is traversed by blood-vessels.

Owing to this arrangement it will be seen that the water tubes all open dorsally into a *suprabranchial chamber*, continuous posteriorly with the cloaca and thus opening on the exterior by the exhalant siphon.

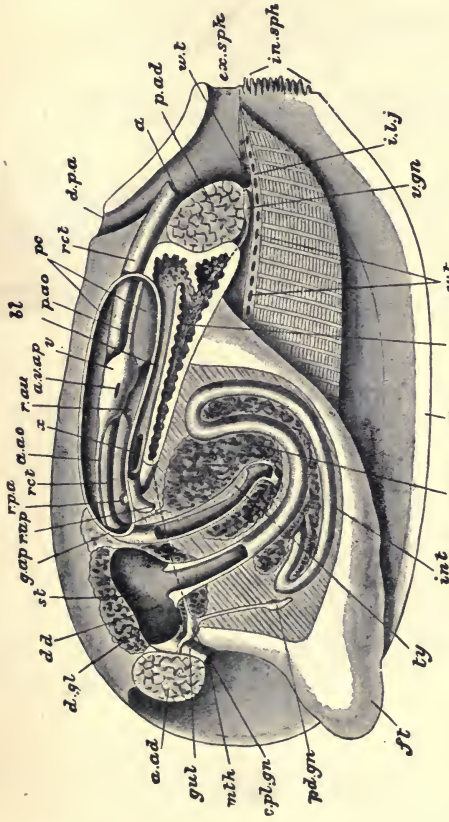
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FIG. 162.—**Anodonta cygnea.** Dissection from the left side. *a*, anus; *a.ad*, anterior adductor; *a.ao*, anterior aorta; *a.v.ap*, auriculo-ventricular aperture; *bl*, urinary bladder; *c.pl.gn*, cerebro-pleural ganglion; *d.d*, duct of digestive gland; *d.gl*, digestive gland; *d.p.a*, dorsal pallial aperture; *ex.sph*, exhalant siphon; *ft*, foot; *g.ap*, genital aperture; *gon*, gonad; *gul*, gullet; *i.l.j*, inter-lamellar junction; *in.sph*, inhalant siphon; *int*, intestine; *kd*, kidney; *m*, mantle; *mth*, mouth; *p.ad*, posterior adductor; *p.ao*, posterior aorta; *pc*, pericardium; *pd.gn*, pedal ganglion; *r.ap*, renal aperture; *r.au*, right auricle; *rct*, rectum; *r.p.a*, reno-pericardial aperture; *st*, stomach; *ty*, typhlosole; *v*, ventricle; *v.gn*, visceral ganglion; *w.t*, water tubes.

The physiological importance of the gills will now be obvious. By the action of their cilia a current is produced which sets in through the inhalant siphon into the pallial cavity, and out at the exhalant siphon. The ingoing current carries with it not only oxygen for the aëration of the blood, but also diatoms, Infusoria, and other microscopic organisms, which are swept into the mouth by the cilia cov-

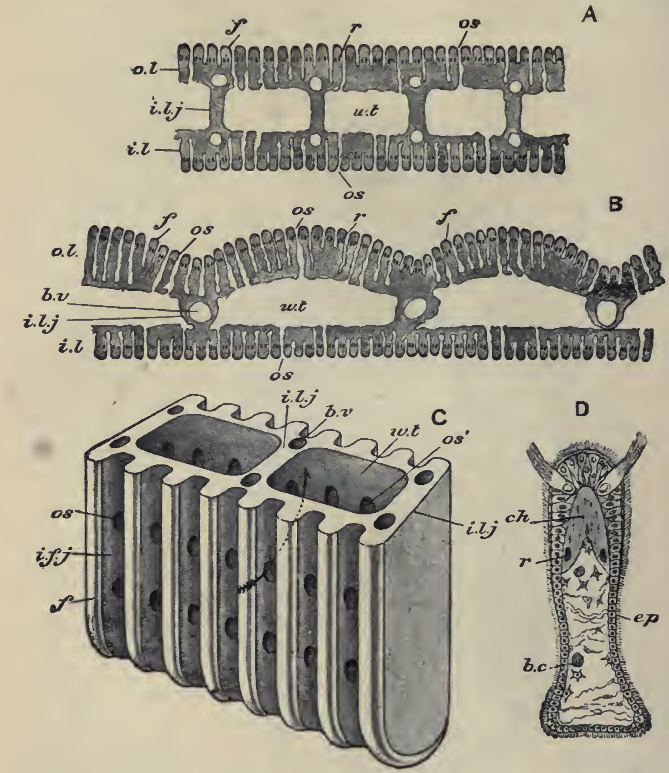
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FIG. 163.—**Anodonta cygnea.** A, transverse section of outer; B, of inner gill; C, diagram of gill-structure; D, transverse section of gill-filament. *b. c*, blood-corpuscle; *b. v*, blood-vessels; *ch*, chitin; *f*, branchial filaments; *ep*, epithelium; *i. f. j*, inter-filamental junction; *i. l*, inner lamella; *i. l. j*, inter-lamellar junction; *o. l*, outer lamella; *os*, external ostium; *os'*, internal ostium; *r*, chitinous rods; *w. t*, water tubes. (A, B, and D, after Peck.)

ering the labial palps. The outgoing current carries with it the various products of excretion and the fæces passed into the cloaca. The action of the gills in producing the food current is of more importance than their respiratory function, which they share with the mantle.

The *excretory organs* are a single pair of curiously modified *nephridia*, situated one on each side of the body just below the pericardium. Each nephridium consists of two parts, a brown spongy *glandular portion* or *kidney* (Fig. 162, *kd*), and a thin-walled non-glandular part or *bladder* (*bl*) communicating with one another posteriorly, while in front the kidney opens into the pericardium (*r. p. ap*), and the bladder on to the exterior by a minute aperture (*r. ap*), situated between the inner gill and the visceral mass. Thus the whole organ, often called after its discoverer, the *organ of Bojanus*, is simply a tube bent upon itself, opening at one end into the cœlom, and at the other on the external surface of the body.

The *circulatory system* is well developed. The *heart* lies in the pericardium and consists of a single *ventricle* (Figs. 162 and 164, *v*) and of right and left *auricles* (*au*). The ventricle is a muscular chamber which has the peculiarity of surrounding the rectum (Fig. 162); the auricles are thin-walled chambers communicating with the ventricle by valvular apertures opening towards the latter. From each end of the ventricle an artery is given off, the *anterior aorta* (Fig. 162, *a. ao*) passing above, the *posterior aorta* (*p. ao*) below the rectum. From the aortæ the blood passes into arteries (Fig. 164, *art. 1*, *art. 2*) which, ramifying all over the body, finally form an extensive network of vessels, many of which are devoid of proper walls and have therefore the nature of sinuses.

The *nervous system* is formed on a type quite different from anything we have yet met with. On each side of the gullet is a small *cerebro-pleural ganglion* (Fig. 162, *c. pl. gn*) united with its fellow of the opposite side by a nerve-cord — the *cerebral commissure* passing about the gullet. Each cerebro-pleural ganglion also gives off a cord, the *cerebro-pedal connective*, which passes downwards and backwards to a *pedal ganglion* (*pd. gn*) situated at the junction of the

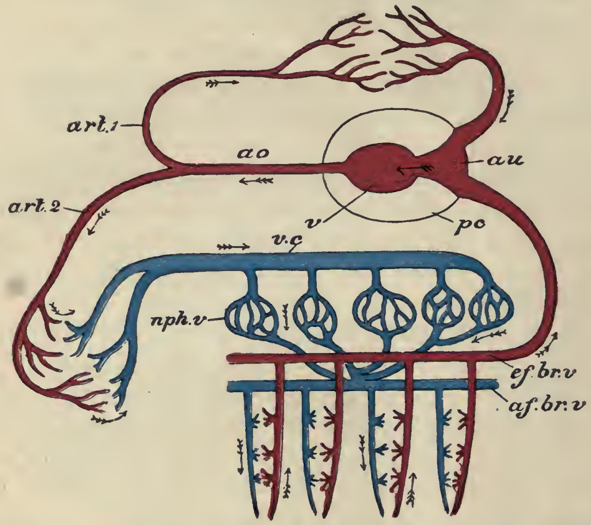

FIG. 164. — Diagram of the circulatory system of **Anodonta**. Vessels containing aërated blood red, non-aërated blue. *af. br. v*, afferent branchial veins; *ao*, aorta; *art. 1*, artery to mantle; *art 2*, artery to body generally; *au*, auricle; *ef. br. v*, efferent branchial veins; *nph. v*, nephridial veins; *pc*, pericardium; *v*, ventricle; *v. c*, vena cava. The arrows show the direction of the current.

visceral mass with the foot; the two pedal ganglia are so closely united as to form a single bilobed mass. From each cerebro-pleural ganglion there further proceeds a long *cerebro-visceral connective* which passes directly backwards through the kidney, and ends in a *visceral ganglion* (*v. gn*) placed on the ventral side of the posterior adductor muscle. The visceral, like the pedal ganglia, are fused together.

Sensory organs are poorly developed, as might be expected in an animal of such sedentary habits. In connection with each visceral ganglion is a patch of sensory epithelium forming the so-called olfactory organ or, better, *osphradium*, the function of which is apparently to test the purity of the water entering by the respiratory current. Close to the pedal ganglion a minute otocyst is sometimes found. Sensory cells — probably tactile — also occur round the edge of the mantle, and especially on the fimbriæ of the inhalant siphon.

The sexes are separate. The *gonads* (Fig. 162, *gon*) are large, paired, racemose glands, occupying a considerable portion of the visceral mass amongst the coils of the intestine; the testis is white, the ovary reddish. The gonad of each side has a short duct which opens (*g. ap*) on the surface of the visceral mass just in front of the renal aperture.

In the breeding season the eggs, extruded from the genital aperture, pass into the suprabranchial chamber and so to the cloaca. There, in all probability, they are impregnated by sperms introduced with the respiratory current. The oosperms are then passed into the cavities of the outer gills, which they distend enormously. Thus the outer gills act as brood-pouches, and in them the embryo develops into a peculiar larval form known as *Glochidium*.

The Glochidium (Fig. 165) has a bivalved shell produced ventrally into incurved hooks beset with spines. After a time it is ejected from the mantle-cavity and falls to the bottom of the water, where it lies until it has the opportunity of becoming attached to the gills or skin of a fish. Fixed firmly by means of the hooked valves the larva remains as an external parasite for about ten weeks, becoming encysted by an overgrowth of the skin or mucous membrane of their host. In the meantime a metamorphosis is taking place, and when the young mussel becomes free it has begun to assume the form and structure of the adult.

The majority of the members of the class **Pelecypoda** resemble the fresh-water mussel in the main features above described. They are bilaterally symmetrical, laterally compressed, with a mantle consisting of paired right and left lobes, secreting a bivalved calcareous shell. A distinct head is never present. There is on the ventral surface a muscular foot; there are two abductor muscles, and there are two pairs of gills. But, on looking over a collection of shells of various bivalves, it will be found that certain of them differ from that of the fresh-water mussel in not having the two valves of the shell alike. This inequality between the two valves of the shell is strongly marked in the scallops, and even more so in the oysters. The oysters are also examples of Pelecypods, which have only one adductor muscle instead of two; and the oyster, which is unable to

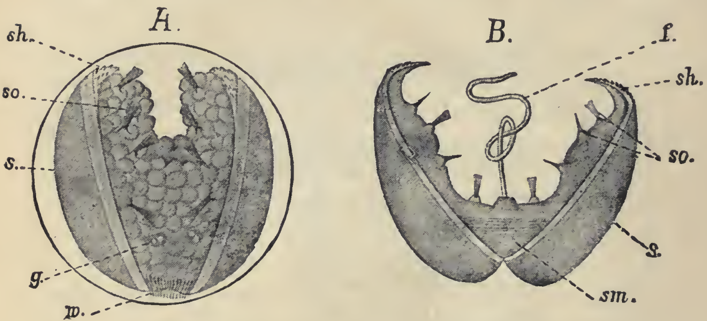

Fig 165. — A, advanced embryo of **Anodonta**; B, free glochidium. *f*, provisional byssus; *s*, shell; *sh*, hooks; *sm*, adductor muscle; *so*, sense organs; *w*, cilia. (From Korschelt and Heider's *Embryology*.)

move from place to place, and in the case of some species is permanently fixed to some rock or other solid body by the substance of the larger valve, has no foot. The inhalant and exhalant siphons are sometimes absent, sometimes much longer than in the fresh-water mussel, as in the clam (*Mya arenaria*). Posterior to the foot there is in many Pelecypods a gland termed the *byssus gland*, secreting silky threads which serve to attach the animal temporarily or permanently, as, for example, in the sea mussel (*Mytilus*) (Fig. 166). In most Pelecypoda the gills (*ctenidia*, p. 271) are simpler in character than in the fresh-water mussels. In one group, *Protobranchia* (*Nucula*, etc.), they take the form of a pair of plume-like organs, and are primitive in shape and structure.

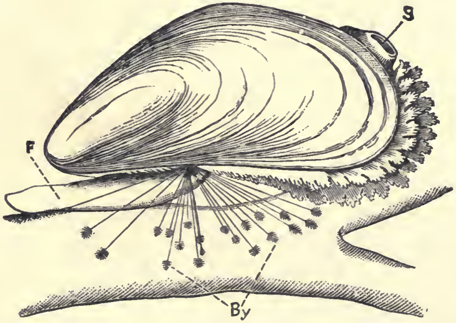

FIG. 166. — **Mytilus edulis**, attached by byssus (By) to a piece of wood. F, foot; S, exhalant siphon. (From the *Cambridge Natural History*.)

A remarkably modified member of this class of molluscs is the ship-worm, *Teredo*, which is very destructive to ships' timbers, piles of jetties, etc. The valves of the shell are extremely small, and the general surface of the mantle secretes a continuous shelly tube lining the burrow in which the elongated worm-like body of the mollusc lies. Highly developed eyes are present in a row round the edge of the mouth in the scallop (*Pecten*) and a few others.

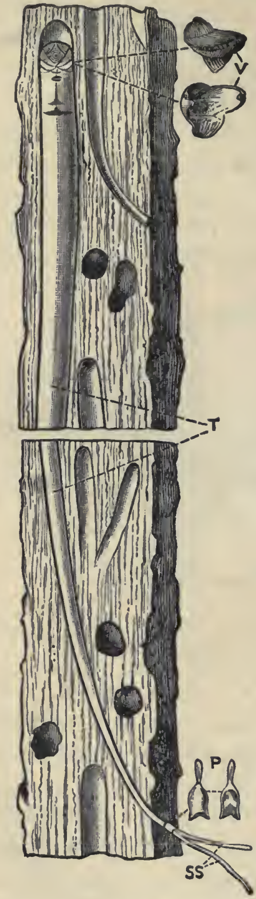

Fig. 167. — **Teredo navalis**, in a piece of timber. P, pallets; SS, siphons; T, tube; V, valve; of shell. (From the *Cambridge Natural History*.)

Although none of the Pelecypoda are microscopic, they present a considerable range in size, from the little fresh-water *Cyclas*, about 1 cm. long, to the giant clam (*Tridacna gigas*) of the Indian and Pacific Islands, which is sometimes 60 cm. (two feet) in length and 500 pounds in weight. The nacreous inner layer of the shell of the pearl oyster (*Meleagrina margaritifera*), which is of unusual thickness, constitutes the "mother-of-pearl" of commerce, employed for many ornamental purposes. Pearls are deposits of nacre formed around sand grains or other foreign bodies, either between the mantle and shell, or in the soft parts in the pearl oyster and the pearl mussel (*Unio complanatus*), etc.

Most Pelecypoda are sluggish in habit, progressing only by slow movements of the foot, and some are permanently fixed during adult life by the byssus. The scallops, however, swim freely by clapping the valves together. The cockles (*Cardium*), *Trigonia*, etc., jump by sudden movements of the foot, and the razor-fish (*Solen*) jerks itself forward by suddenly withdrawing its very large foot, and thus ejecting water through the siphons. The only parasitic genus is *Entovalva,* found in the gullet of a Holothurian.

Pelecypoda are abundant both in fresh water and the sea; the marine forms are mainly littoral. None are pelagic or terrestrial.

2. THE AMPHINEURA

A class of molluscs which comprises only a small number of representatives, most of them of rare occurrence and of simple organisation, is the Amphineura. With the exception of the Chitons these have no shell and are devoid of a foot, so that though probably related to the more typical molluscs, and to be referred to the same phylum, they are wanted in some of the most characteristic features exhibited by the members of the other classes. All the Amphineura are bilaterally symmetrical, more or less elongated molluscs, with the mouth at the anterior and the anus at the posterior end.

The commonest, as well as the most highly organised, of the Amphineura are the Chitons, marine molluscs which are to be found adhering firmly, like limpets, to rocks and stones on the seashore, or in deep water. The body is dorso-ventrally compressed, convex above, and presents below a broad flat foot (narrow in *Chitonellus*), which acts not only as an organ for effecting creeping movements, but also as a sucker for enabling the animal when at rest to adhere firmly, like a limpet, to the surface of a rock. The most remarkable external feature of the Chiton is the presence on the dorsal surface of a calcareous shell (Fig. 168), made up of no fewer than eight transversely elongated pieces or valves, arranged in a longitudinal row, artic-

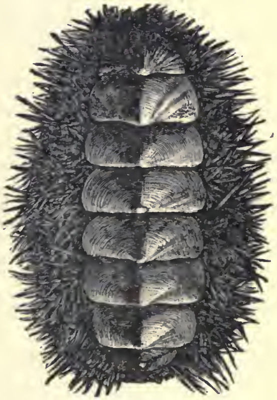

FIG. 168 — **Chiton spinosus,** dorsal view. (From the *Cambridge Natural History.*)

ulating together and partly overlapping one another. They are sometimes partly, sometimes completely, covered over by the mantle. Each valve consists of two very distinct layers, a more superficial and a deeper, the latter formed of a compact calcareous substance, the former perforated by numerous vertical canals for the lodgment of the sense organs, to be presently referred to. External to the valves the dorsal integument (mantle) of Chiton and its allies is usually beset with a number of horny or calcified tubercles and spicules. The mantle develops only very slight lateral flaps, and under cover of these are a series of small gills or ctenidia (Fig. 169, *ctn*), to the number of fourteen to eighty. The mouth and anus are both median, situated at the anterior and posterior extremities respectively.

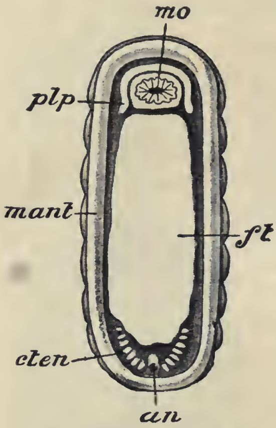

FIG. 169. — **Chiton**, ventral view. *an*, anus; *cten*, ctenidia; *ft*, foot; *mant*, mantle edge; *mo*, mouth. (After Pelseneer.)

The buccal cavity always contains a well-developed odontophore. The intestine is elongated and coiled. There are salivary glands and a large paired liver. There is a well-developed heart, consisting of a median ventricle and two lateral auricles. The pericardial cavity in which it lies is a space of considerable extent in the posterior region of the body, below the two last valves of the shell.

The central part of the nervous system comprises an œsophageal nerve-ring, consisting of a thicker dorsal *cerebral* portion not differentiated into ganglia, and a thinner ventral *buccal commissure*. Two pairs of longitudinal nerve-cords, *pedal* and *pallial*, are given off from this posteriorly. The former, which give off nerves to the foot, are joined by numerous commissures passing beneath the enteric canal. The large cords contain nerve-cells throughout their length.

The conspicuous organs of special sense present on the head of Gastropods (see p. 289) are absent in the Chitons. A pair of processes situated in front at the sides of the mouth have the character of labial palps. Remarkable sensory organs, the *micræsthetes* and the *megalæsthetes*, lie in the canals already mentioned as occurring in the superficial layer of the shell valves. The megalæsthetes may take the form of eyes, with cornea, lens, pigment layer with iris, and retina.

There are two symmetrical nephridia (Fig. 170) opening internally into the pericardium by a ciliated funnel-like opening (*n. peri. ap*), and opening on the exterior (*neph. ap*), between two of the posterior ctenidia. Each consists of a looped main tube, into which open numerous minute tubules which ramify among the viscera. The sexes are distinct. The testis and ovary (*gon*) are similar in appearance,

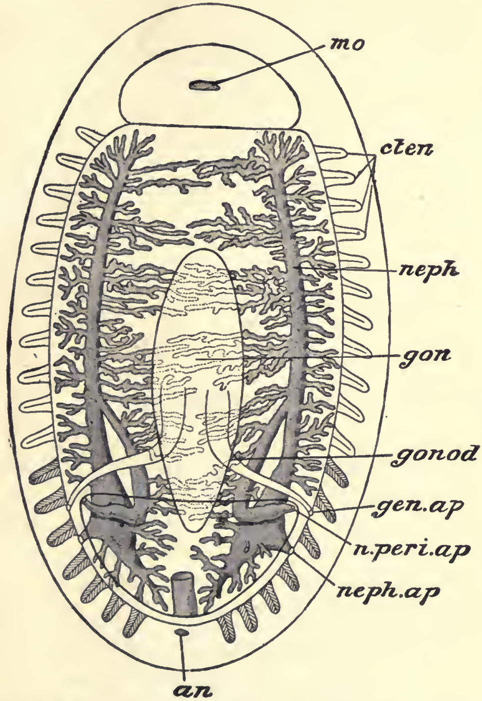

FIG. 170. — **Chiton**, nephridial and genital systems. *an*, anus; *cten*, ctenidia; *gen. ap*, genital aperture; *gon*, gonad; *gonod*, gonoduct; *mo*, mouth; *neph. ap*, nephridial aperture; *n. peri. ap*, aperture from nephridia to pericardium. (From Simroth, after Haller and Lang.)

differing only in colour when the products are mature. Each is an unpaired sac marked by a series of slight lateral constrictions. The larva is a Trochosphere.

All the Amphineura are marine. The Placophora (Chitons) occur at all depths, though most abundant on the shores between tidal limits. The shell-less forms (Aplacophora), on the other hand, are rare in very shallow water, and absent altogether from the littoral zone; some have been found at considerable depths (down to 1250 fathoms). The Placophora are all vegetable feeders, their food consisting of minute algæ and diatoms. The Aplacophora subsist on small animals. The Placophora, when at rest, adhere firmly to the surface of a rock or a block of coral by means of the sucker-like foot. When forcibly detached the animal curls itself up into a ball, and will only after a considerable time slowly extend itself again. All their movements are extremely sluggish. The Aplacophora are unable to fix themselves in this way; many of them occur twined round the stems of zoophytes, sometimes attached by a thread of viscid mucus.

3. THE GASTROPODA

The class **Gastropoda** comprises the snails and slugs, limpets, whelks, periwinkles, sea-hares, and the like. They are distinguished by the possession of a shell of a univalve character, consisting of a single piece, and by the mantle not being developed into two lateral folds, as in the Pelecypoda. There is a distinct head, bearing eyes and tentacles. The body is inequilateral, and the foot is ventrally situated, forming a large creeping disc.

If we look at a living Gastropod, such as a snail (Fig. 171) when fully extended, the want of symmetry appears at first sight to be limited to the spiral shell, which is in itself unsymmetrical, and is held obliquely, the head part and the "tail" part appearing when superficially examined, quite bilaterally symmetrical. But a closer examination, especially after removal of the shell, shows that the departure from symmetry is very marked. The left side of the body has become very much more strongly developed than the right, and this side of the body is drawn out into a spirally twisted prominence — the *visceral spiral* — enclosing the liver and other organs. The anal aperture, instead of being median and posterior, is situated on the right side, and in front of it on the same side is the reproductive aperture.

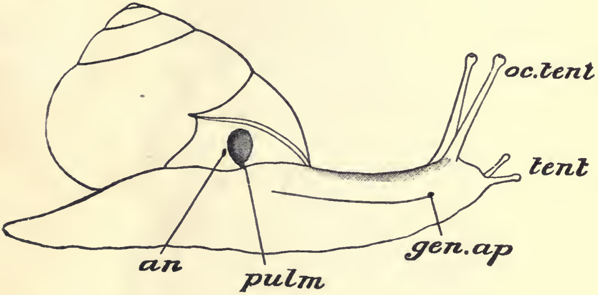

FIG. 171. — **Helix nemoralis.** *an*, anus; *gen. ap*, genital aperture; *oc. tent.* posterior eye-bearing tentacles; *pulm*, opening of pulmonary sac; *tent*, anterior tentacles. (After Pelseneer.)

The shell is of simple conical form in the limpets. In most of the Gastropoda it is in the shape of a spiral (Figs. 172, 173) with the turns usually in close contact with one another, the inner walls of the turns coalescing to form an axial, hollow, or solid column — the *columella*. By far the greater number of such spiral shells are *dextral*, *i.e.*, if we begin at the apex of the spiral to reach the opening of the shell we have to pass from left to right with the columella always on our right-hand side; in a few cases, however, the spiral is *sinistral*, taking the opposite direction from that of the ordinary dextral shell. The form of the shell varies with the degree of obliquity with which the whorls are set on the axis. When the obliquity is very slight (Fig. 174), the spiral is nearly flat; when the obliquity is great, an elongated tapering shell, such as that represented in Fig. 175, is the result. Sometimes the later whorls completely cover over the earlier ones, so that the spiral form of the shell is concealed. Sometimes only the apical portion of the shell is spiral, the remainder being a straight or sinuous cylinder. The mouth of the shell has usually a prominent margin or

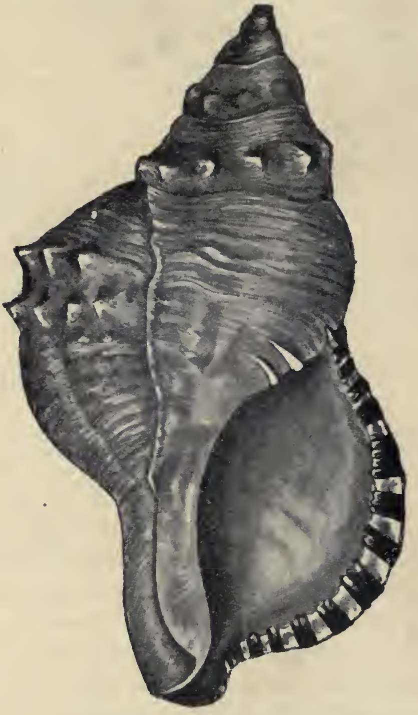

FIG. 172.—Shell of **Triton nodiferus**. Natural size. New Zealand.

peristome, which is sometimes entire and continuous, sometimes is broken by a deep notch or a spout-like prolongation or *canal*, formed in connection with the development

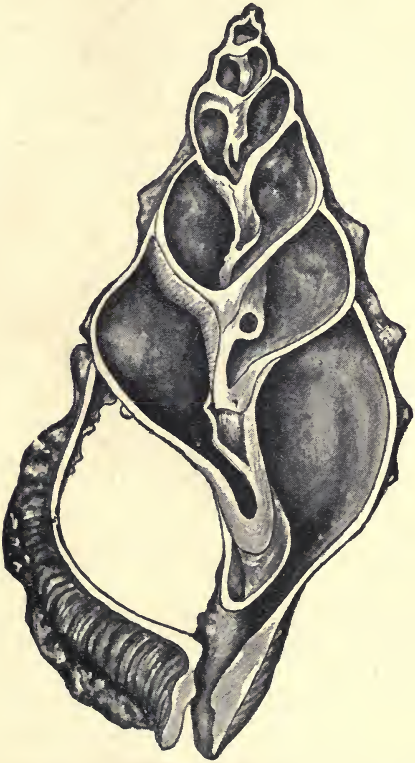

FIG. 173. — Longitudinal median section of the shell of **Triton nodiferus.**

of a spout-like prolongation of the mantle, the *siphon*, which lies in it. The mouth of the shell in many Gastropoda is capable of being closed by means of an operculum borne on the foot. In some terrestrial forms in which an operculum is absent, the opening may be closed up during winter by a layer of hardened mucous matter to which the name of *epiphragm* is applied. Lateral folds of the mantle are in some of the Gastropoda (Fig. 176) reflected over the shell, and may completely cover it. In some cases these folds unite by their edge, so that the shell comes to be enclosed in a complete sac of the mantle; such enclosed shells are always imperfectly developed and incapable of covering the body. Thus in *Aplysia* (the "Sea-hare") and other allied forms the shell is greatly reduced, thin and horny, and concealed within the mantle, while in the nudibranch (Fig. 177), members of the same sub-order, it is entirely absent. The shell is also completely absent in some of the pelagic forms (*Heteropoda* and *Pteropoda*); in others, though present and external, it is too small to enclose the animal. In the slugs the shell is vestigial and concealed by the mantle.

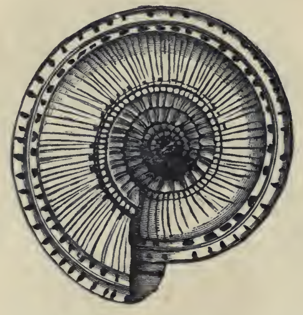

FIG. 174. — **Shell of Solarium perspectivum from the under side.** (From the *Cambridge Natural History.*)

The Gastropoda have a well-marked *head*, separated from the body by a constriction or *neck*. The mouth, situated at the anterior end of the head on its ventral aspect, is in many instances provided with a protrusible probosis or *introvert*, sometimes of considerable length. On the dorsal surface of the head are a pair of tentacles which vary a good deal in shape, but are usually cylindrical or club-shaped. In most cases the eyes are situated on tubercules at the bases of the tentacles, or elevated towards the middle; but in the snails and slugs (*Pulmonata*) (Fig. 171) the eyes are elevated on the extremities of a second, longer pair of tentacles (*oc. tent*) placed behind the first.

The *mantle* is usually developed into a fold, the *mantle-flap*, originally posterior, but subsequently becoming shifted round to the right-hand side. This covers over a cavity, the *mantle-cavity*, situated anteriorly, in which are situated the anal and nephridial apertures and the ctenidia. The edges of the mantle-flap may become united together in such a way as to form a chamber opening on the exterior by a comparatively narrow opening. In many the edges of this aperture are drawn out into a spout-like prolongation open ventrally, the *siphon*, which lies in the corresponding prolongation of the peristome of the shell, and serves as a channel for the ingress and egress of water. In some Gastropods, however, there is no definite mantle-cavity, the anus, nephridial apertures, and ctenidia merely lying under cover of a comparatively slightly developed lateral mantle-flap.

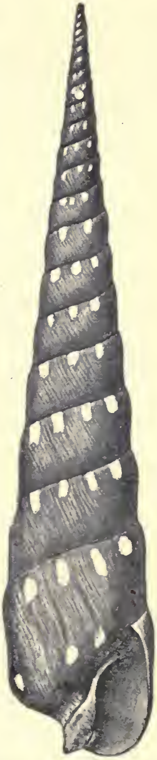
FIG. 175. — Shell of Terebra oculata.

The *foot* varies in the extent of its development in the different families of the class. It usually presents an elongated, flat, ventral surface on which the animal creeps by wave-like contractions of the muscular tissue. In the typical Gastropods the foot is usually distinguishable into three parts, a middle part or *mesopodium* which is the most important, with a smaller anterior *propodium* and posterior *metapodium*. The whole foot becomes reduced in a few Gastropods that remain fixed. The metapodium very fre-

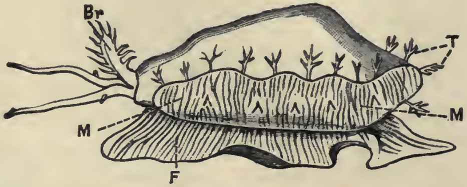

FIG. 176. — **Cypræa moneta** (Cowrie). Showing the mantle, provided with marginal tentacles, partly enveloping the shell. *Br*, branchia; M, M, mantle; F, foot; T, tentacles at the edge of the mantle. (From Cooke, after Quoy and Gaimard.)

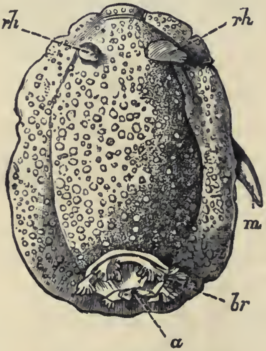

FIG. 177. — **Doris (Archidoris) tuberculata**. *a*, anus; *br*, branchiæ; *m*, penis; *rh*, *rh*, tentacles. (From the *Cambridge Natural History*.)

quently bears a disc or stopper, the *operculum*, usually horny, or partly calcified, by means of which the aperture of the shell is closed when the animal is retracted.

In some forms, such as the sea-hares (*Aplysia*), the foot develops a pair of lateral lobes, the *epipodia*, which act as fins; and in the Pteropods (Fig. 178), which are specially modified for a pelagic existence, these constitute the largest part of the foot.

The organs of respiration in the majority of the aquatic Gastropoda are in the form of gills or *ctenidia*, usually plume-shaped appendages consisting of a central stem bearing two rows of compressed filaments or lamellæ, or a single row. Two ctenidia may be present or only one may be developed; they are enclosed in the mantle-cavity.

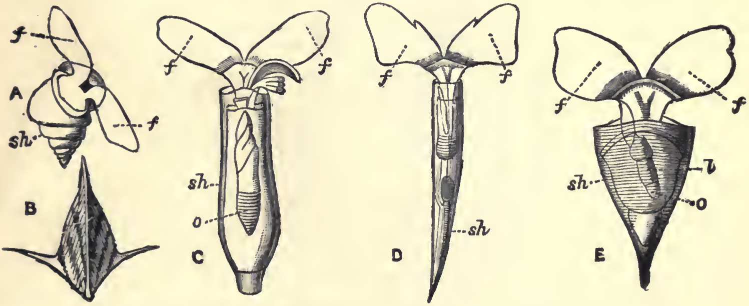

FIG. 178. — Shell-bearing Pteropoda. *f, f*, fins; *l*, liver; *o*, ovary; *sh*, shell. (From Cooke, after Souleyet.)

In the Nudibranchs two ctenidia are absent, but their place as breathing organs is taken by a number of *secondary branchiæ*, sometimes simple, sometimes branched or pinnate processes, which are distributed over the dorsal surface, as in *Eolis*, or as in *Doris* (Fig. 177), forming a circlet surrounding the anus, or, as in *Pleurophyllidia*, a row on each side beneath the mantle-flap.

In the limpets (*Patella* and its allies[1]) (Fig. 179) the true ctenidia are represented only by a pair of vestiges, and respiration is carried on by a number of secondary branchiæ (*g. l*) in the form of lamellæ situated between the short lateral fold of the mantle and the foot. In the Pulmonata, and in some members of other groups, ctenidia are absent, and the mantle-cavity, completely enclosed except for a small rounded opening, has the function of a *pulmonary sac* or *lung* (Fig. 180), its roof being richly supplied with blood-vessels; in the aquatic forms its function is apparently as much hydrostatic as respiratory. In some of the Pulmonata there is a return to a completely aquatic mode of respiration accompanied by the development of

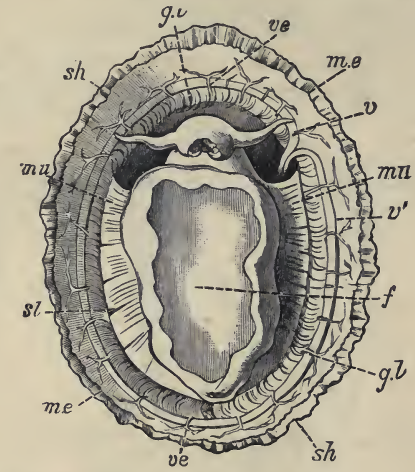

FIG. 179.—**Patella vulgata**, seen from the ventral side. *f*, foot; *g. l*, circlet of gill lamellæ; *m. e*, edge of the mantle; *mu*, attachment muscle; *sl*, slits in the attachment muscle; *sh*, shell; *v*, efferent branchial vessel; *v'*, aorta; *ve*, smaller vessels. (From the *Cambridge Natural History*.)

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[1] Our common eastern American limpet is *Acmæa testudinalis*.

secondary gills — vascular processes of the wall of the mantle-cavity.

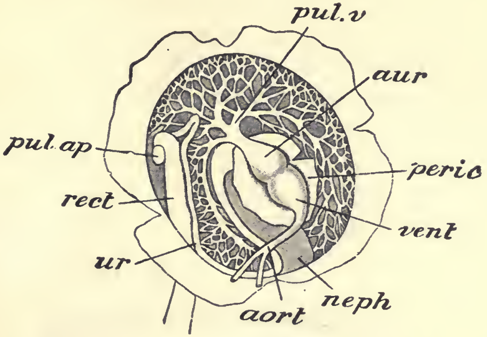

FIG. 180. — Pulmonary cavity and related parts in a slug (**Limax**). *aort*, aorta; *aur*, auricle; *neph*, nephridium; *peric*, pericardium, laid open; *pul. ap*, pulmonary aperture; *pul. v*, pulmonary vein with its ramifications; *rect*, rectum; *ur*, ureter; *vent*, ventricle. (After Pelseneer.)

Digestive Organs. — In many Gastropods there is a long *proboscis* capable of being everted and retracted, at the extremity of which the mouth is placed. A single curved horny jaw lies on the roof of the buccal cavity in the Pulmonata; in most marine Gastropoda the place of this is taken by two lateral pieces.

A characteristic feature of the alimentary canal of the Gastropoda, which, however, they share with some Amphineura and with the Cephalopoda, is the possession of an odontophore and radula, situated in a thick-walled chamber, the *buccal cavity*, into which the mouth opens. From the floor of the cavity rises an elevation, the *odontophore*, which is somewhat elongated in the direction of the long axis of the body and compressed laterally. Over the summit of the odontophore runs longitudinally a narrow strap-like body, the *radula* or *lingual ribbon* (Fig. 181, *rad*), beset with numerous minute horny or siliceous teeth arranged in transverse rows. Posteriorly this toothed ribbon extends into a narrow curved pouch, the *radular sac* (Fig. 181, *rad. sac*), extending backwards from the posterior and lower aspect of the buccal cavity. Anteriorly it does not extend beyond the odontophore prominence. The latter contains cartilages (*cart*), serving for the support of the whole apparatus, and is capable of being extruded, with the radula which it bears, through the opening of the mouth by the contraction of sets of protractor muscular fibres. Inserted into the radula itself are sets of bands of muscular fibres by which it can be drawn backwards and forwards over the odontophore as over a pulley, the effect being a rasping of any hard substance against which it is pressed. The entire buccal cavity is capable of being drawn forwards towards the mouth opening, or backwards into the introvert, by the contraction of strands of muscular fibres passing from its wall to the wall of the body.

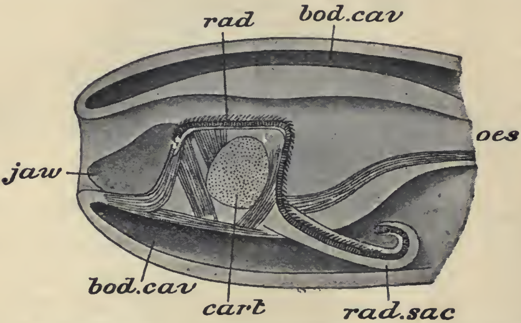

FIG. 181.—**Triton nodiferus.** Diagrammatic longitudinal vertical section of buccal cavity. *bod. cav*, body cavity; *cart*, cartilage of odontophore; *jaw*, right jaw; *œs*, œsophagus; *rad*, radula; *rad. sac*, radula sac.

The heart is enclosed, as in the fresh-water mussel, in a cavity, the *pericardium*. It consists, in nearly all cases, of only two chambers, an auricle and a ventricle.

The nervous system and organs of special sense are in most Gastropoda more highly developed than they are in the fresh-water mussel. There are distinct cerebral and pleural, as well as pedal and visceral, ganglia. Well-developed eyes are present in the majority, and there are otocysts, osphradia or water-testing organs, and usually olfactory organs in the shape of special groups of cells on the tentacles.

The nephridia are granular tubes or chambers communicating, as in the fresh-water mussel, with the pericardial cavity on the one hand, and with the exterior on the other. Two nephridia right and left may be present, or only one.

The sexes are separate in some Gastropoda; in others, such as the snails and slugs, they are united; and in the latter case their structure is highly complex. The larva is a Trochosphere, which subsequently develops into a form known as the Veliger. In the Veliger the prototroch, or ciliated præ-oral ridge of the Trophosphere, becomes drawn out into a bilobed flap bordered with strong cilia. There is a shell, a distinct foot bearing an operculum, and tentacles and eyes are present on the head-region. The shell is at first of simple conical form and the anus is placed in the middle line posteriorly. It is only as development advances that one side of the body becomes more rapidly developed than the other, and the anus becomes shifted forwards, the shell at the same time in the great majority taking on a spiral form, and the visceral prominence enclosed within it acquiring a corresponding shape.

Two main divisions or sub-classes of the Gastropoda are recognised — the *Streptoneura* and the *Euthyneura*. The former comprises the majority of the marine univalves, such as the limpets, ear-shells, cowries, tritons, whelks, and cones. The latter includes the water-breathing sea-hares and nudibranchs and the air-breathing snails and slugs. The chief general points of distinction between the two groups are that in the Streptoneura the visceral nerve-cords are twisted into a figure 8, and the sexes are separate, while in the Euthyneura the twisting of the nerve-cords is absent and the sexes are united in the same individual.

Only a few aberrant families of Gastropoda are parasites. Most are aquatic, all the most primitive forms being inhabitants of the sea. Of the marine families the majority move by creeping over the sea-bottom, some burrowing in mud or sand, some in solid rock; some are able to float in a reversed position, adhering to frothy mucus secreted by the glands of the foot; certain exceptional forms such as *Vermetus* are fixed in the adult condition by the substance of the shell. A few families — the Heteropoda and the Pteropoda — are specially modified for a pelagic mode of existence, and swim through the water by flapping movements of the lobes of the foot, which act as fins. Gastropods are found at considerable depths — up to nearly three thousand fathoms — in the ocean. Many forms, however, are inhabitants of fresh water, while many Pulmonata are terrestrial, and occur even towards the summits of the highest mountains.

4. THE CEPHALOPODA

The class **Cephalopoda**, including the cuttle-fishes, squids, Octopi, argonauts, and Nautili, is the highest of the Mollusca, its members being very much more active and powerful in their movements than the rest of the Mollusca, and much more highly endowed as regard their higher senses. The body (Figs. 182, 183, 185, 187) is bilaterally symmetrical. The foot, instead of extending along the ventral surface

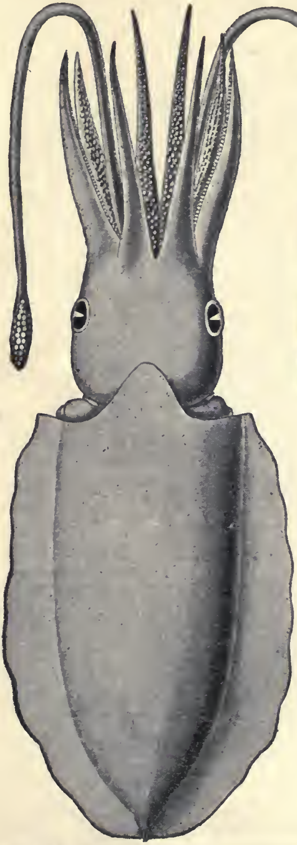

FIG. 182. — **Sepia cultrata.** Entire animal viewed from the dorsal aspect. New Zealand.

of the body in the region behind the mouth, as it does in Pelecypoda and Gastropoda, occupies a more anterior position, and surrounds the mouth. A distinct head is present, and the foot assumes the appearance of a system of appendages of the head. In the cuttle-fishes (Fig. 182), squids (Fig. 187), Octopi, and Argonauts (constituting the sub-class Dibranchiata) the main part of the foot is composed

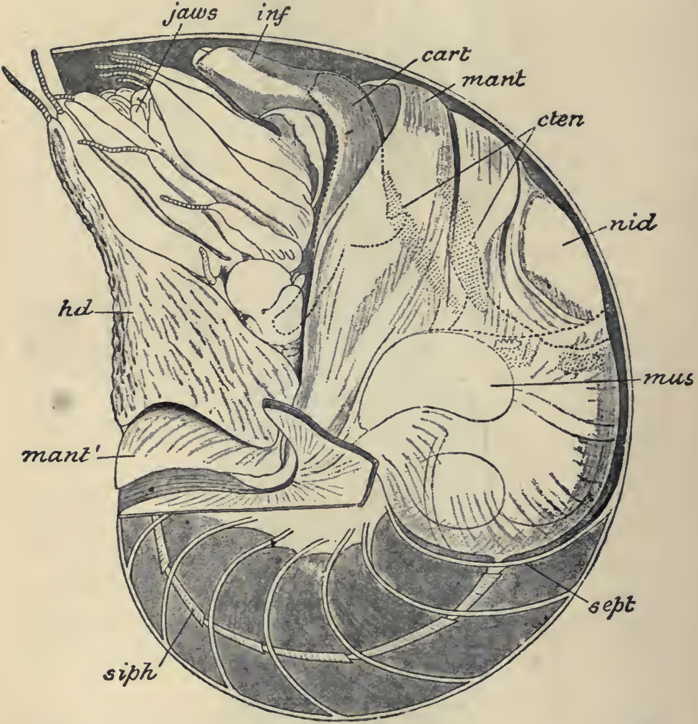

FIG. 183.—**Nautilus pompilius**, diagrammatic lateral view of a female specimen enclosed in its shell. *cart*, cartilage; *cten*, ctenidia; *hd*, hood; *inf*, funnel; *jaws*, jaws; *mant*, mantle; *mant'*, dorsal mantle-fold overlapping the coil of the shell; *mus*, position of lateral mass of muscle; *nid*, nidamental glands; *sept*, first septum; *siph*, siphuncle. (After Keferstein.)

of either eight or ten long, highly extensible and contractile appendages, the *arms*, the inner surfaces of which are beset with numerous suckers, rendering them powerful grasping organs. These are arranged in a circlet surrounding the mouth. The posterior part of the foot appears to be represented by the *funnel*, a wide tube through which water is driven out from the mantle-cavity. In the Nautili (Fig. 183), (sub-class Tetrabranchiata), the place of the arms with their suckers is taken by a number of lobes bearing sheathed tentacles surrounding the mouth, and a funnel is also present, though it does not form a complete tube.

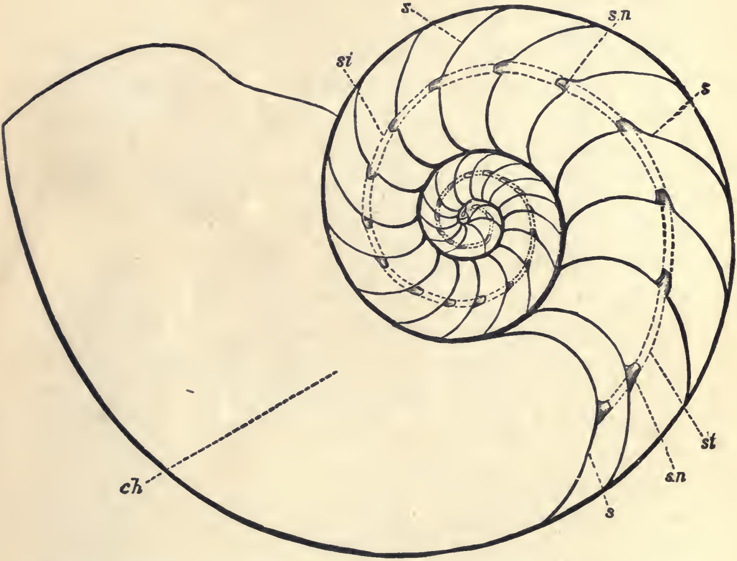

FIG. 184. — Section of the shell of **Nautilus pompilius**, showing the septa (*s*, *s*), the septal necks (*s. n.*, *s. n.*), the siphuncle (*si*, represented by dotted lines), and the large body-chamber (*ch*). (From the *Cambridge Natural History*.)

To compare such a cephalopod as a cuttle-fish or squid with a fresh-water mussel or a snail, it is advisable to place it in a position which it quite naturally assumes when not swimming, with the head and its arms downwards and the body sloping away from this upwards and backwards. In this position we distinguish antero-dorsal and postero-ventral surfaces, oral and aboral extremities, and right and left borders. A shell is present in nearly all Cephalopods, but is only external in the female argonaut and in Nautilus. In the latter (Fig. 184) it is in the form of a flat spiral, the interior of which is divided by a series of transverse partitions or septa into a corresponding series of chambers. The last chamber opens widely on the exterior, and this alone lodges the body of the animal, the remaining chambers being filled with gas.

Perforating the middle of all the septa in succession is a spiral tube — the *siphuncle* — continuous with the centro-dorsal region of the visceral prominence. In the course of its growth the body of the Nautilus shifts forwards at intervals into a newly formed chamber, and a new septum is formed closing the latter off from the cavity last occupied.

The Nautilus inhabits the coral reefs of the Pacific, at a depth of a few fathoms. Of existing Dibranchiata, *Spirula* (Fig. 185) alone has a shell comparable to that of Nautilus. The shell of Spirula is of spiral form, the turns of the spiral, however, not being in close contact. Internally it is divided into chambers by a series of septa, and these are perforated by a siphuncle. Again, as will be seen by comparing Figs. 183 and 185, the relation of the soft parts to the shell is the reverse of what obtains in Nautilus, the shell of Spirula curving backwards, that of Nautilus forwards. Moreover the shell of Spirula is an internal structure, being almost completely covered by the mantle. Its shell has been found cast ashore on Nantucket.

In the other Dibranchiata the shell may consist of three parts, — a horny *pen* or *pro-ostracum*, a calcareous *guard*, and a part termed the *phragmocone*. The last, which alone represents the shell of *Spirula*, has the form of a cone divided internally by a series of septa perforated by a siphuncle. These parts are most completely developed in the extinct genus *Belemnites*, in which the shell consists of a straight, conical, chambered phragmocone, with a siphuncle, enclosed in a calcareous sheath, the guard, produced into a horny or calcareous plate, the pro-ostracum. In the cuttle-fish of the Mediterranean Sea (*Sepia*) the shell is a leaf-like body, with a rounded and comparatively broad oral end, and a narrower aboral provided with a sharp projecting spine. The main mass of the shell consists of numerous, closely arranged, thin laminæ of calcareous composition, between which are interspaces containing gas. The spine-like projecting point represents the guard, and the main substance of the shell is to be looked upon as the pro-ostracum and phragmocone, the septa of the latter being represented by the calcareous

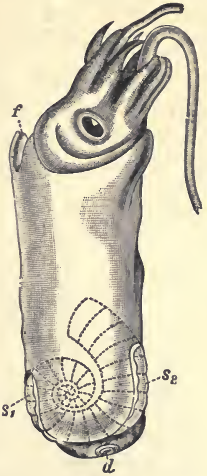

FIG. 185. — **Spirula peronii**, lateral view. *d*, terminal sucker; *f*, funnel; s_1, s_2, projecting portions of the shell, the internal part of which is indicated by dotted lines. (From Cooke.)

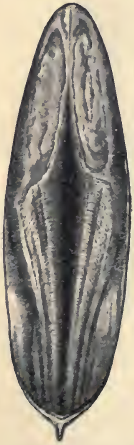

FIG. 186. — **Shell of Sepia cultrata**, posterior view, reduced.

lamellæ. In *Loligo*[1] (the squids) the shell (Fig. 187, B) is long, narrow, and completely horny; it corresponds to the pro-ostracum, the phragmocone being entirely absent.

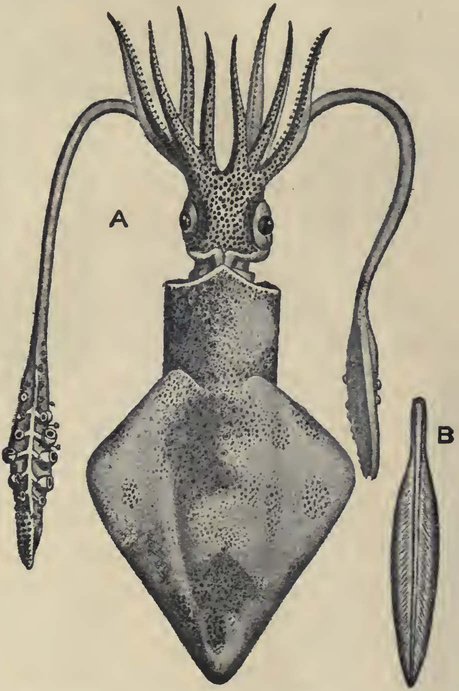

Fig. 187.—**Loligo vulgaris.** A, entire animal, dorsal view; B, horny internal shell or pen. (From Keferstein.)

In *Octopus* the shell is represented only by a pair of rudiments with which muscles are connected. In *Argonauta* there is no shell in the male, but the female has an external shell (Fig. 188) of a remarkable character. This is a delicate spiral structure, the internal cavity of which is not divided into chambers. It is not secreted by the mantle like the shells of other Mollusca, but by the surfaces of a pair of the arms ending in expanded disc-like extremities, which become applied to its outer surface; its chief function is to carry the eggs. The argonaut inhabits deep water, 70 to 100 miles off the coast of New England, its shells being in very rare cases found cast ashore on our coast south of Cape Cod.

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[1] Our common American species is *Loligo pealii.*

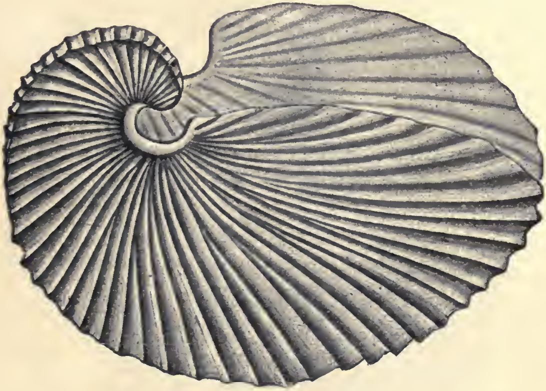

FIG. 188. — Shell of **Argonauto argo.**

In addition to the shell there is in all the Cephalopoda an internal skeleton of cartilage supporting and protecting the nerve-centres and other parts.

The cuttle-fishes and other Dibranchiata when alive will be observed to undergo frequent changes of colour, and blushes of different hues are to be noticed passing over the surface. These are due to the presence of numerous contractile, pigment-containing cells or *chromatophores*, situated in the deeper layers of the integument over the entire surface, which contract and expand under nervous influence (Fig. 189).

On the postero-ventral aspect of the body the mantle encloses a wide cavity, the *mantle-cavity* (Figs. 190, 191), in which the ctenidia are lodged, and on the wall of which are situated the anal, excretory, and reproductive apertures. The mantle-cavity communicates at its oral end by a wide slit with the exterior; but this is capable of being closed, so that, when the walls of the cavity contract, a stream of water is ejected through the funnel, and the animal is propelled in the aboral direction. Swimming is also effected in the Dibranchiata by means of a pair of fins in the shape of muscular, lateral flaps. The ctenidia (*cten*) are plume-like, and are either two (*Dibranchiata*) or four (*Tetrabranchiata*) in number.

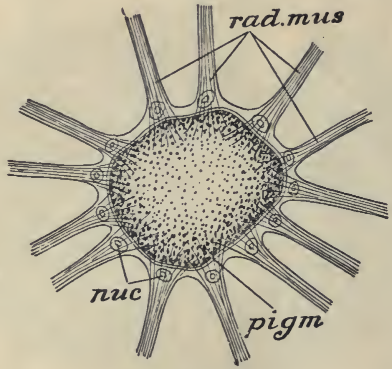

FIG. 189. — Chromatophore of **Sepia**, magnified. *nuc*, nuclei in wall of sac; *pigm*, pigment; *rad. mus*, radiating strands of muscle. (After Vogt and Jung.)

The mouth is provided with a pair of horny or calcified jaws (Fig. 192, B) similar in shape to the jaws of a parrot. The buccal cavity contains an odontophore. Opening into

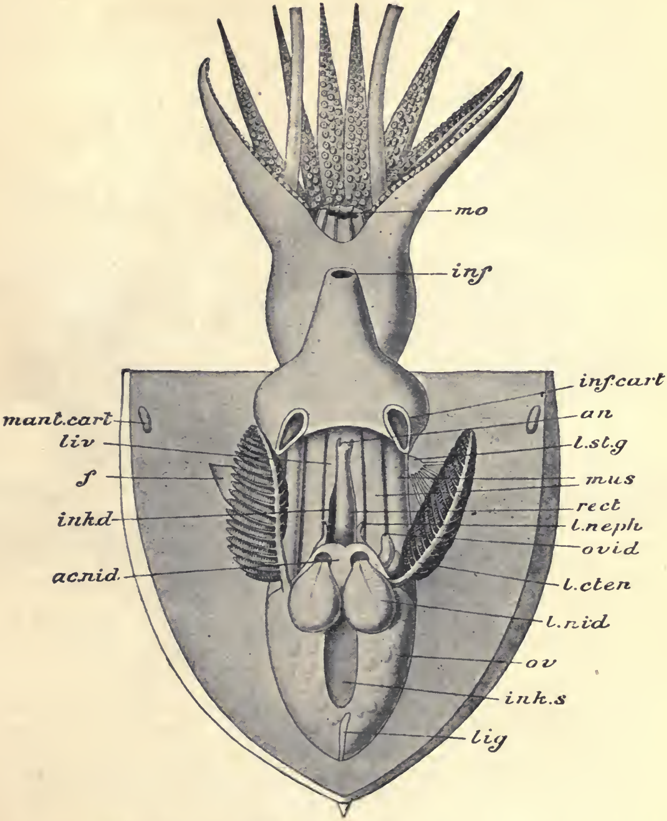
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FIG. 190.—**Sepia cultrata,** female seen from the posterior aspect, the wall of the mantle-cavity divided along the middle line and the two flaps thus formed spread out so as to expose the contents. *ac. nid*, accessory nidamental glands; *an*, anal aperture with its lateral appendages; *f*, membranous fold attaching the ctenidium to the wall of the mantle-cavity; *inf*, external opening of funnel; *inf. cart*, infundibular cartilage; *ink. s*, ink-sac; *ink. d*, ink-duct; *lig*, ligamentous band which extends from the anterior wall of the mantle-cavity to the ovary, cut across; *liv*, liver; *l. cten*, left ctenidium; *l. neph*, left nephridial aperture; *l.nid*, left nidamental gland; *l. st. g*, left stellate ganglion; *mant. cart*, mantle cartilage; *mo*, mouth; *mus*, neck muscles; *ov*, ovary; *ovid*, oviduct; *rec*, rectum.

the terminal part of the intestine close to the anal aperture is the duct of a peculiar gland — the *ink gland* (Fig. 193, *i*). This secretes a black substance, the *ink*, which is discharged when the animal is irritated or alarmed, and mingling with the water in the mantle-cavity is discharged as a dark cloud, under cover of which the animal may elude the pursuit of an enemy.

The heart and vascular system reaches a high stage of development. The heart consists of a median ventricle and two or four elongated lateral auricles or branchio-cardiac vessels conveying the blood from the ctenidia to the ventricle.

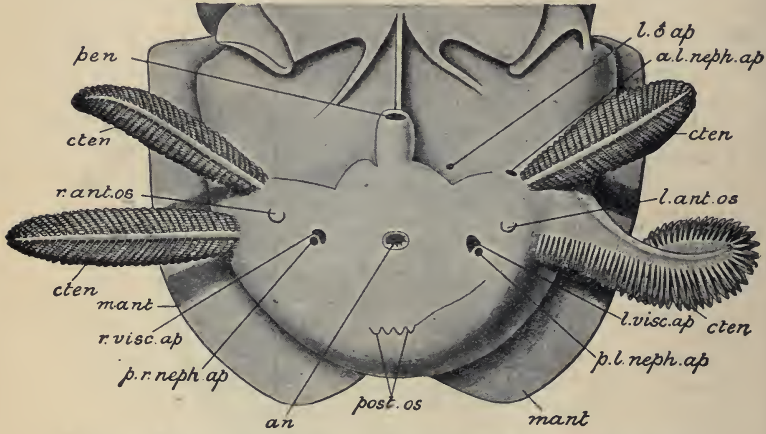

FIG. 191. — **Nautilus pompilius**, interior of mantle-cavity of a male specimen with the postero-ventral wall reflected. *a. l. neph. ap*, oral left nephridial aperture; *an*, anus: *cten*, ctenidia: *l. ♂ ap*, left reproductive aperture: *l. ant. os*, left oral osphradium: *l visc ap*, left viscero-pericardial aperture; *mant*, flaps of mantle; *pen*, penis: *p l. neph ap*, aboral left nephridial aperture: *p. r. neph. ap*, aboral right nephridial aperture; *post. os*, aboral osphradia; *r. visc. ap*, right viscero-pericardial aperture.

The nervous system is highly developed, and its principal central parts, representing the cerebral, pedal, and visceral ganglia of other molluscs, with their commissures and connectives, form a ring round the gullet. There are a pair of large eyes situated on the head. In the cuttle-fishes and other Dibranchiata these have a highly complicated structure, and contain representatives of all the principal parts of the eye of a fish or other vertebrate. In Nautilus the eye is of

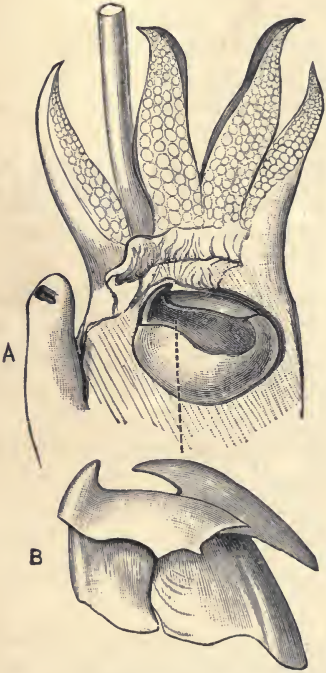

FIG. 192. — **Sepia officinalis**, jaws. A, *in situ;* B, removed and slightly enlarged. (From the *Cambridge Natural History*.)

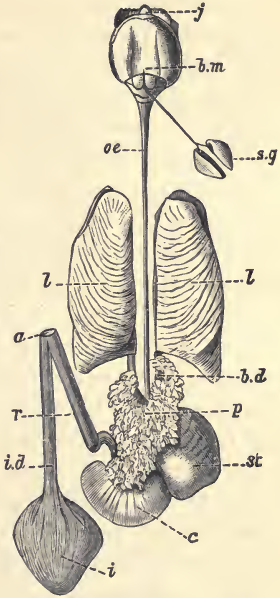

FIG. 193. — **Sepia officinalis**, enteric canal. *a*, anus; *b. d*, one of the bile ducts; *b. m*, buccal mass; *c*, cæcum; *i*, ink-sac; *i. d*, ink-duct; *j*, jaws; *l*, *l*, liver lobes; *œ*, œsophagus; *p*, pancreatic appendages[1]; *r*, rectum; *s. g*, salivary glands; *st*, stomach (From the *Cambridge Natural History*.)

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[1] This organ is by Sedgwick regarded as renal in its nature, being the unpaired portion of the kidneys. (See Sedgwick's *Text-book of Zoology*, i, pp. 433, 437.)

much simpler structure. There is a pair of otocysts, and sensory processes or depressions supposed to be olfactory are also present. Osphradia occur only in Nautilus.

There are either two (*Dibranchiata*) or four (*Tetrabranchiata*) nephridia, which are in the form of sacs opening into the mantle-cavity, and in the Dibranchiata communicating with the pericardium. Through each of these runs one of the principal veins, round which the secreting tissue of the nephridium is aggregated.

The sexes are distinct. The ova are always large, containing a large quantity of yolk. No metamorphosis, such as is general in other groups of Mollusca, is known to occur in any Cephalopod.

The Cephalopoda are all marine, and range from tidal limits to a considerable depth. Squids swim like fishes in schools, rising to the surface and darting out of the water, and sometimes leaping so vigorously as to fall on the decks of large vessels. A large number are pelagic. They are, nearly without exception, carnivorous. In length they range from an inch or two to as much as fifty feet — the gigantic members of the group, such as *Architeuthis*, being by a long way the largest of invertebrate animals, and like the other classes of Mollusca they are most abundant in tropical and warm temperate seas.

As already stated, the class is divided into two sub-classes, the Dibranchiata and the Tetrabranchiata — the latter comprising only the Nautili (in addition to many fossil forms), the former including all the rest of the living members of the class. In the former the forefoot assumes the character of a circlet of either eight or ten arms bearing suckers surrounding the mouth. The funnel forms a complete tube. The shell is usually internal; when external its cavity is not divided by septa. There are two ctenidia, two nephridia, and two auricles. An ink gland is present. In the latter, on the other hand, the forefoot has the character of lobes bearing tentacles; the funnel does not form a complete tube. There is an external, chambered, spiral shell. There are four ctenidia, four nephridia, and four auricles. The ink gland is absent.

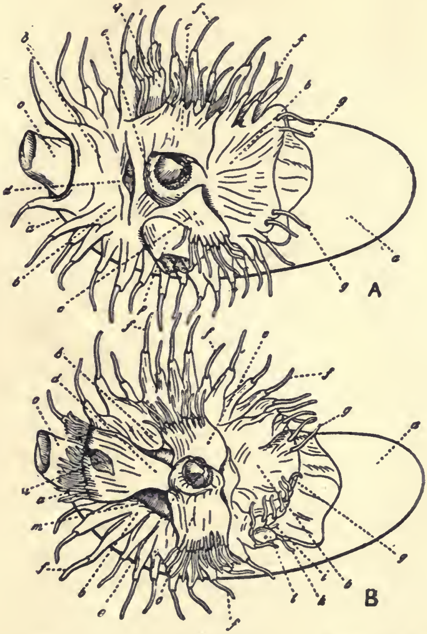

FIG. 194. — Oral surface of a male (A) and female (B) **Nautilus pompilius** in an expanded state, ⅓ natural size, linear. *a*, shell; *b*, external annular lobe carrying 19 tentacles on each side, and anteriorly enlarged to form the hood; *c*, right and left inner lobes, each carrying 12 tentacles in the female, and divided in the male into two parts; *d*, posterior inner lobe; *e*, oral cone; *f*, tentacles of the outer annular lobe projecting from their sheaths; *g*, two anterior tentacles of this lobe belonging to the hood; *i*, superior, *k*, inferior, ophthalmic tentacle; *l*, eye; *n*, lamellated organ on the posterior inner lobe of the female; *m*, paired laminated organ on each side of the posterior inner lobe of the female; *o*, funnel; *p*, spadix; *q*, antispadix. (After Bourne, from Sedgwick.)

SECTION XII. — PHYLUM CHORDATA

The Phylum Chordata comprises all the vertebrate animals (fishes, amphibians, reptiles, birds, and mammals), together with the Urochorda or ~~Ascidians~~, and the Adelochorda or Balanoglossus and its allies. The name Chordata is derived from one of the most important of the few but striking common features by which the members of this extensive phylum are united together — the possession, either in the young condition, or throughout life, of a structure termed the *chorda dorsalis* or *notochord*. This is a cord only of cells, typically developed from the endoderm, extending along the middle line on the dorsal side of the enteric cavity, and on the ventral side of the central part of the nervous system. It becomes enclosed in a firm sheath and forms an elastic supporting structure. In the Vertebrata (with the exception of Amphioxus and the lampreys and hag fishes) it becomes in the adult replaced more or less completely by a segmented bony or cartilaginous axis — the spinal or vertebral column. Another nearly universal common feature of the Chordata is the perforation of the wall of the pharynx, either in the embryonic or larval condition only, or throughout life, by a system of clefts — the branchial clefts; and a third is the almost universal presence at all stages, or only in the larva, of a cavity or system of cavities, the *neurocœle*, in the interior of the body, lying above the central nervous system.

(Hemichordata.)

1. THE ADELOCHORDA

Of somewhat doubtful relationships both to one another and to the other Chordata are certain remarkable marine animals which have been grouped together under the name of Hemichorda or Adelochorda. These are *Balanoglossus* and its allies, which occur in shallow water on the coasts of most of the warmer parts of the world, and two are deep-sea animals, *Rhabdopleura* and *Cephalodiscus*.

Balanoglossus (Fig. 195) is a soft-bodied, cylindrical, worm-like animal, the surface of which is uniformly ciliated. It is divisible into three regions: ① in front there is a large, club-shaped, hollow organ — the *proboscis*; ② immediately behind the proboscis and encircling its base is a prominent fold — the *collar*; ③ the third region or *trunk* is long and nearly cylindrical, but somewhat depressed.

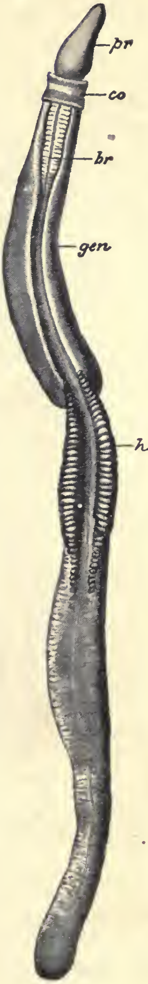

FIG. 195. — **Balanoglossus.** Entire animal. *br*, branchial region; *co*, collar; *gen*, genital ridges; *hep*, prominences formed by hepatic cœca; *pr*, proboscis. (After Spengel.)

Balanoglossus lives in the sea, burrowing in sand or mud by means of its proboscis. It occurs as far north as Salem, Mass., between tide-marks. Numerous glands in the integument secrete a viscid matter to which grains of sand adhere in such a way as to form a fragile temporary tube. The proboscis (Fig. 195, *pr*, Fig. 196, *prob*) has muscular walls; its cavity opens on the exterior usually by a single minute aperture — the *proboscis pore* (Fig. 196, *prob. po*) — rarely by two. The collar (Fig. 195, *co*) is also muscular, and contains one cavity or two (right and left) separated from one another by dorsal and ventral mesenteries, and completely cut off from the proboscis. The collar cavity communicates with the exterior by a pair of *collar pores* — ciliated tubes leading into the first gill-slit or first gill-pouch.

On the dorsal surface of the anterior part of the trunk is a double row of small slits — the *gill-slits* (Fig. 195, *br*,) — each row situated in a longitudinal furrow; these slits increase in number throughout. The cœlom of the trunk is divided into two lateral closed cavities by a vertical partition (dorsal and ventral mesenteries).

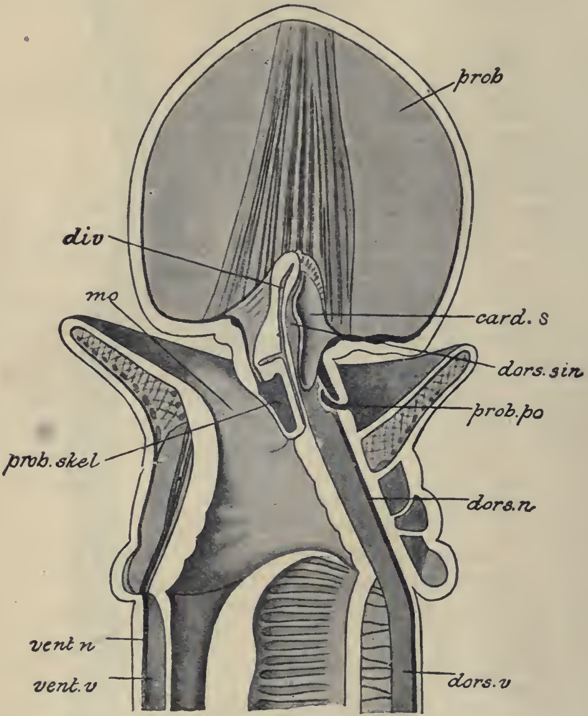

FIG. 196. — **Balanoglossus.** Diagrammatic sagittal section of anterior end. *card. s*, cardiac sac; *div*, diverticulum (supposed notochord); *dors. n*, dorsal nerve strand; *dors. sin*, dorsal sinus; *dors. v*, dorsal vessel; *mo*, mouth; *prob*, proboscis; *prob. po*, proboscis pore; *prob. skel*, proboscis skeleton; *vent. n*, ventral nerve strand; *vent. v*, ventral vessel. (After Spengel.)

The mouth (Fig. 196, *mo*,) is situated ventrally at the base of the proboscis, within the collar. Into the dorsal half of the anterior portion of the alimentary canal open the internal gill-openings. The gill-pouches are supported by a chitinoid skeleton consisting of a number of separate parts.

The posterior part of the alimentary canal is a nearly straight tube with, in its middle part, paired *hepatic cœca* (Fig. 195, *hep*), which bulge outwards in a series of external prominences. Posteriorly it terminates in an anal aperture situated at the posterior extremity of the body. Throughout its length it lies between the dorsal and ventral divisions of the vertical partition, which act as mesenteries.

In front the dorsal wall of this anterior portion of the alimentary canal gives off a diverticulum (Fig. 196, *div*), the lumen of which extends nearly to the anterior end. This diverticulum consists of epithelium with gland cells and of a sort of retiform connective tissue; it is supposed to be homologous with the *notochord* of the typical Chordata.

There is a blood-vascular system with dorsal (*dors. v*) and ventral (*vent. v*) longitudinal trunks. The nervous system consists of dorsal (*dors. n*) and ventral strands (*vent. n*), which extend throughout the length of the body. The part of the dorsal cord which lies in the collar lies deeper than the rest, and contains a canal or a number of spaces. Between the collar and the trunk the dorsal and ventral strands are connected by a ring-like thickening. There are no organs of special sense.

The sexes are separate; the ovaries and testes are saccular organs arranged in a double row along the branchial region of the trunk and further back; they open on the exterior by a series of pores.

The course of the development differs in different species. In some it is comparatively direct; in others there is a metamorphosis. In the latter case the embryo assumes a larval form termed *Tornaria*, which is somewhat like an Echinoderm larva, with a pair of ciliated bands, one of which is considered præ-oral, and the other post-oral, and an independent circlet of strong cilia at the posterior end.

Usually associated with Balanoglossus are two aberrant animals — *Cephalodiscus* and *Rhabdopleura* — formerly regarded as Polyozoa. These both resemble Balanoglossus in having the body divided into three parts or regions — a proboscis, with a proboscis cavity, a *collar* with a collar-cavity communicating with the exterior by a pair of collar-pores, and a *trunk* with two distinct lateral cavities; and in the presence of a structure resembling a notochord with the same relations to the nervous system as in Balanoglossus. They both differ from Balanoglossus in having the alimentary canal bent on itself, so that the anal opening is situated not far from the mouth, in the presence of tentacles arising from the collar; and in the comparatively small size of the proboscis.

2. THE UROCHORDA

Still more unlike a vertebrate in general appearance than Balanoglossus, and yet, as the earlier stages show, indubitably to be assigned to the Chordate phylum, are the **Ascidians** or Sea-squirts and their allies.

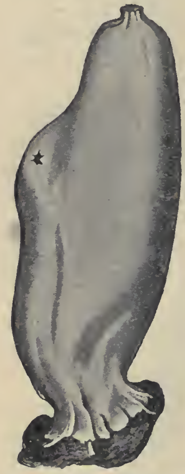

FIG. 197.—**Ascidia**, entire animal seen from the right-hand side. (After Herdman.)

Sea-squirts are familiar objects on rocky sea-shores, where they occur often in large associations, adhering firmly to the surface of the rock. They also live free in sand and in mud, at different depths, some being deep-sea forms. When touched the Ascidian ejects with considerable force two fine jets of sea-water, which are found to proceed from two apertures on its upper end. The shape of the Ascidian, however, can only be profitably studied in the case of specimens that are completely immersed in the sea-water, specimens not so immersed always undergoing contraction. In an uncontracted specimen[1] (Fig. 197) the general shape is that of a short cylinder with a broad base by which it is fixed to the rock. The free end presents a large rounded aperture, and some little distance from it on one side is a second of similar character. The former aperture is termed the *oral*, the latter the *atrial*. A strong current of water will be noticed, by watching the movements of floating particles, to be flowing steadily in at the former and out of the latter. When the animal is removed from the water both apertures become narrowed, so as to be almost completely closed, by the contraction of sphincters of muscular fibres which surround them. At the same time the walls of the body contract, streams of water are forced out through the apertures, and the bulk becomes considerably reduced.

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[1] The European species, whose anatomy is here described, is approximately represented by our common large *Ascidia callosa*, which lives in deep water off the Maine coast.

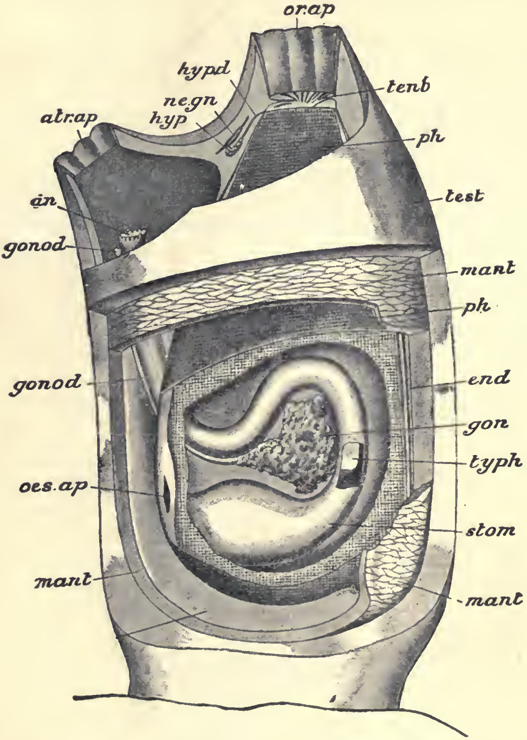

FIG. 198. — Dissection of **Ascidia** from the right-hand side. The greater part of the test and mantle has been removed from that side so as to bring into view the relations of these layers and of the internal cavities and the course of the alimentary canal, etc. *an*, anus; *atr. ap*, atrial aperture; *end*, endostyle; *gon*, gonad; *gonod*, gonoduct; *hyp*, hypophysis; *hyp. d*, duct of hypophysis; *mant.* mantle; *ne. gn*, nerve-ganglion; *œs. ap*, aperture of œsophagus; *or. ap*, oral aperture; *ph*, pharynx; *stom*, stomach; *tent*, tentacles; *test*, test. (After Herdman.)

The outer layer of the body-wall is composed of a tough translucent substance forming a thick *test* or *tunic* (Fig. 198, *test*). This proves, when analysed, to consist largely of the substance *cellulose*, which has already been referred to (p. 36) as a characteristic component of the tissues of plants, and which is rare in its occurrence in the animal kingdom.

When the test is divided (Fig. 198), the soft wall of the body or *mantle* (*mant*), as it is termed, comes into view, and the body is found to be freely suspended within the test, attached firmly to the latter only round the oral and atrial apertures. The mantle follows the general shape of the test, and at the two apertures is produced into short and wide tubular prolongations, which are known respectively as the *oral* and *atrial siphons* (Fig. 199, *atr. siph*). These are continuous at their margins with the margins of the apertures of the test, and round the openings are the strong sphincter muscles by which closure is effected. Within the body-wall is a cavity, the *atrial* or *peribranchial cavity* (*atr. cav*) communicating with the exterior through the atrial aperture.

The oral aperture leads by a short and wide oral passage into a chamber of large dimensions, the *pharynx* or *branchial chamber* (*ph*). This is a highly characteristic organ of the Urochorda. Its walls are pierced by a number of slit-like apertures, the *stigmata* (Fig. 199, *stig*) arranged in transverse rows. Through these the cavity of the pharynx communicates with the atrial or peribranchial cavity, which completely surrounds it except along one side. The edges of the stigmata are beset with numerous strong cilia, the action of which is to drive currents of water from the pharynx into the atrial cavity. It is to the movements of these cilia lining the stigmata that are due the currents of water already mentioned as flowing into the oral and out of the atrial apertures, the ciliary action drawing a current in through the oral aperture, driving it through the stigmata into the atrial cavity, whence it reaches the exterior through the atrial aperture. The stigmata are all vertical in position; those of the same row are placed close together, separated only by narrow vertical bars; neighbouring rows are separated by somewhat thicker horizontal bars; in all of these bars run blood-vessels.

It has been already mentioned that the atrial cavity does not completely surround the pharynx on one side. This is owing to the fact that on the side in question, which is ventral in position, the wall of the pharynx is united with the mantle along the middle line. Along the line of adhesion the inner surface of the pharynx presents a thickening in the form of a pair of longitudinal folds separated by a groove. To this structure, consisting of the two ventral longitudinal folds with the groove between them, the term *endostyle* is applied. The cells covering the endostyle are large cells of two kinds — *ciliated cells* and *gland cells*, — the former beset at their free ends with cilia, the action of which is

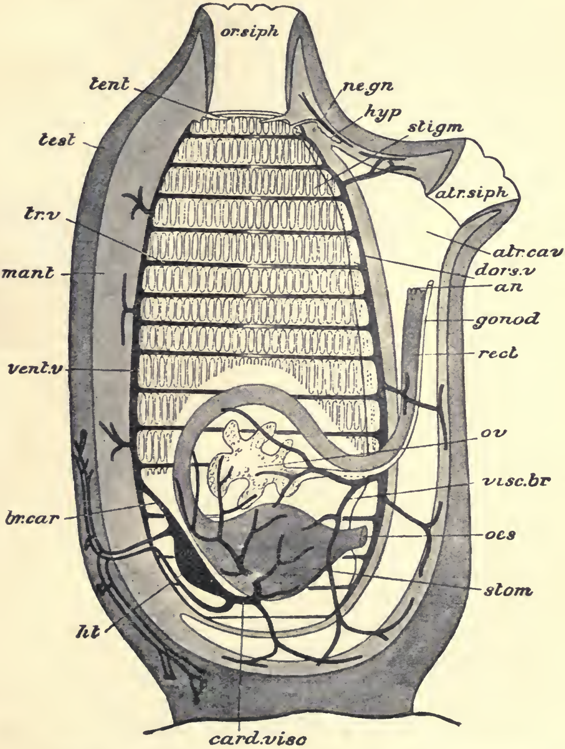
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FIG. 199. — **Ascidia**, diagram of longitudinal section from the left-hand side, the test and mantle removed. *atr. cav*, atrial cavity; *atr. siph*, atrial siphon; *br. car*, branchio-cardiac vessel; *card. visc*, cardio-visceral vessel; *gonod*, gonoduct; *ht*, heart; *hyp*, hypophysis; *mant*, mantle; *n. gn*, nerve-ganglion; *œs*, œsophagus; *ov*, ovary; *rect*, rectum; *stig*, stigmata; *stom*, stomach; *tent*, tentacles; *test*, testis; *tr. v*, transverse vessel; *vent. v*, ventral vessel; *visc. br*, viscero-branchial vessel. (After Herdman.)

to drive floating particles that come within their influence outwards towards the oral aperture, the latter secreting and discharging a viscid mucous matter. Anteriorly the endostyle is continuous with a ciliated ridge which runs circularly round the anterior end of the pharynx. In front of this circular ridge, and running parallel with it, separated from it only by a narrow groove, is another ridge of similar character; these are termed the *peri-pharyngeal ridges*, the groove between them is the *peri-pharyngeal groove*. Dorsally, *i.e.*, opposite the endostyle, the posterior peri-pharyngeal ridge passes into a median, much more prominent, longitudinal ridge, the *dorsal lamina*, which runs along the middle of the dorsal surface of the pharynx to the opening of the œsophagus. The mucus secreted by the gland cells of the endostyle forms viscid threads which entangle food-particles (microscopic organisms of various kinds); the cilia of its ciliated cells drive these forwards to the peri-branchial groove, around which they pass to the dorsal lamina, and the cilia of the cells of the latter drive them backwards to the opening of the œsophagus.

Some little distance in front of the anterior peri-pharyngeal ridge, at the inner or posterior end of the oral siphon, is a circlet of delicate *tentacles* (Fig. 198, *tent*).

The œsophagus leads from the pharynx (near the posterior end of the dorsal lamina) to the stomach, which, together with the intestine, lies embedded in the mantle on the left-hand side. The stomach is a large fusiform sac. The intestine is bent round into a double loop, and runs forwards to terminate in an *anal* aperture, situated in the atrial cavity. There is no liver; but the walls of the stomach are glandular, and a system of delicate tubercles which ramify over the wall of the intestine is supposed to be of the nature of a digestive gland.

The Ascidian has a well-developed blood system. The heart is a simple muscular sac, situated near the stomach in a pericardium forming part of the primitive cœlom. Its mode of pulsation is very remarkable. The contractions are of a peristaltic character, and follow one another from one end of the heart to the other for a certain time; then follows a short pause, and, when the contractions begin again, they have the opposite direction. Thus the direction of the current of blood through the heart is reversed at regular intervals.

The nervous system is of an extremely simple character. There is a single nerve-ganglion, which lies between the oral and atrial apertures, embedded in the mantle. This is elongated in the dorso-ventral direction, and gives off at each end nerves which pass to the various parts of the body.

Lying on the ventral side of the nerve-ganglion is a gland — the *subneural gland.* A duct runs forward from it and opens into the cavity of the pharynx; the termination of the duct is dilated, and this terminal dilatation is folded on itself in a complicated way to form a tubercle, the *dorsal tubercle,* which projects into the cavity of the pharynx.

The excretory system is represented by a single nephridium, which consists of a mass of clear vesicles, without a duct, lying in the second loop of the intestine.

The sexes are united. The ovary and the testis are closely united together, and lie on the left-hand side of the body in the intestinal loop. Continuous with the cavity of each is a duct — *oviduct* or *spermiduct,* as the case may be — which opens into the atrial cavity close to the anus.

So far we have met with no feature that could with certainty be looked upon as indicating alliances with the Chordata. But, though the adult Ascidian is devoid of any such features, there is in the course of its life-history a larval stage in which Chordate affinities are unmistakably indicated. In this stage the young Ascidian is free-swimming, and in general shape bears some resemblance to a minute tadpole, consisting of an oval trunk and a long, laterally compressed tail. The tail is fringed with a caudal fin, which is merely a delicate outgrowth of the thin test covering the whole of the surface; running through the delicate fringe are a series of striæ presenting somewhat the appearance of the fin-rays of a fish's fin. At the anterior end are three processes, the *adhesive papillæ.* In the axis of the tail is the notochord (*noto*), which at this stage consists of a cylindrical cord of gelatinous substance enclosed in a layer of cells. Parallel with this runs, on the dorsal side, the narrow caudal portion of the nerve-cord, and at the sides are bands, or muscular fibres. In the trunk the nerve-cord is dilated, and, further forwards, expands into a vesicle, the *sense vesicle* (*sens. ves*) with an otocyst (*oto*) and a well-developed eye (*eye*). The enteric canal is distinguishable into pharynx, œsophagus, stomach, and intestine. The pharynx opens on the exterior by the mouth: in its ventral floor the endostyle (*end*) has become developed; its walls are pierced by stigmata, the number of which varies; a ciliated sac opens into it below the trunk part of the nerve-cord. The atrial cavity has become formed round the pharynx, and opens on the exterior by a single aperture (*atr*). The heart and pericardial cavity have become developed. In this tailed, free-swimming stage the larva remains only a few hours; it soon becomes fixed by the adhesive papillæ, and begins to undergo the *retrogressive metamorphosis* by which it attains the adult condition.

The chief changes involved in the retrogressive metamorphosis (Figs. 200 and 201) are increase in the number of pharyngeal stigmata, the diminution, and eventually the complete disappearance, of the tail with the contained notochord and caudal part of the nerve-cord, the disappearance of the eye and the otocyst, the dwindling of the trunk part of the nervous system to a single ganglion and the formation of the reproductive organs. Thus, from an active, free-swimming larva, with well-developed organs of special sense, and provided with a notochord and well-developed nervous system, there is a retrogression to the fixed inert adult, in which all the parts indicative of affinities with the Vertebrata have become aborted.

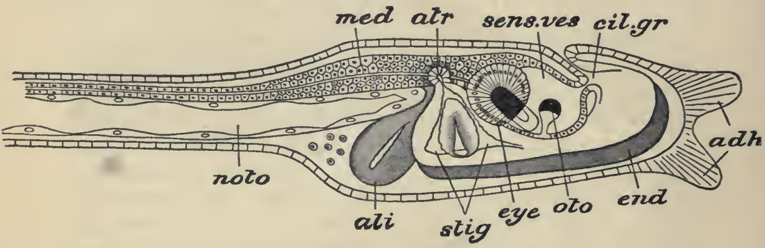

FIG. 200 — Free-swimming larva of **Ascidia mammillata**, lateral view. *adh*, adhesive papillæ; *ali*, alimentary canal; *atr*, atrial aperture; *cil. gr*, ciliated groove; *end*, endostyle; *eye*, eye; *med*, nerve-cord; *noto*, notochord; *oto*, otocyst; *sens. ves*, sense vesicle; *stig*, earliest stigmata. (From Korschelt and Heider, after Kowalewsky.)

A remarkable feature of the Ascidians is that, though many remain simple, others give rise to colonies by a process of budding. In some of these compound forms, distinguished as the *Composite* Ascidians, the tests of the zooids are united together to form a mass of gelatinous consistency in which the zooids of the colony lie embedded (Fig. 202). These compound forms, such as Amaroucium, are common on the New England coast in shallow water.

A minute animal which swims about in the surface waters of the sea has in most respects an extremely close resemblance to the tailed larva

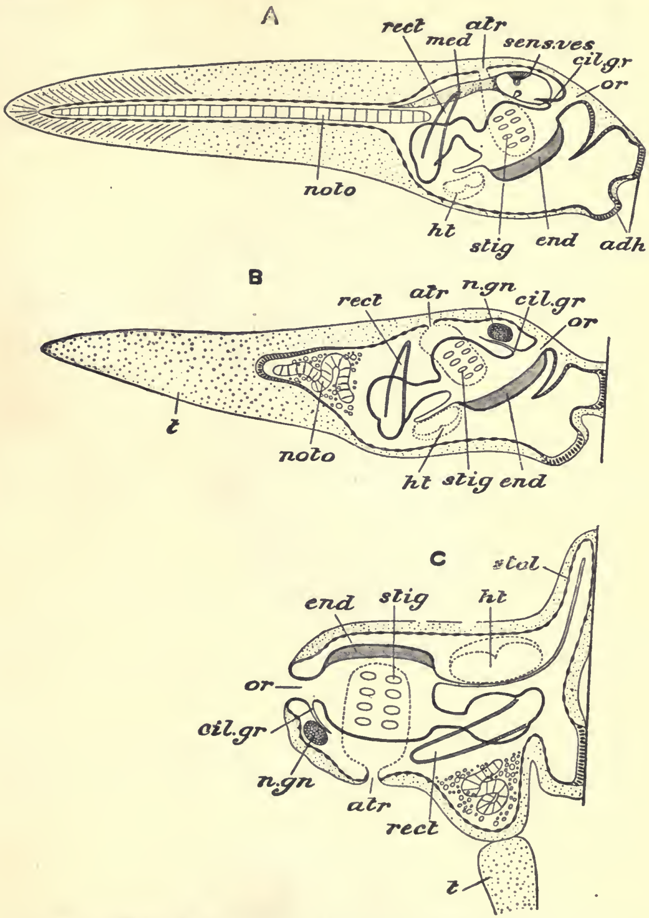
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FIG. 201. — Diagram of the metamorphosis of the free, tailed larva into the fixed Ascidian. A, stage of free-swimming larva; B, larva recently fixed; C, older fixed stage. *adh*, adhesive papillæ; *atr*, atrial cavity; *cil. gr*, ciliated groove; *end*, endostyle; *ht*, heart; *med*, ganglion of trunk; *n. gn*, nerve-ganglion; *noto*, notochord; *or*, oral aperture; *rect*, rectum; *sens. ves*, sense vesicle; *stig*, stigmata; *stol*, stolon; *t*, tail. (From Korschelt and Heider, after Seeliger.)

of an Ascidian, being of similar shape, with a rounded body and a long tail-like appendage attached to the ventral side, and with a distinct notochord. This, however, is an adult animal, known as *Appendicularia.* It never becomes fixed and retains permanently its chordate characteristics.

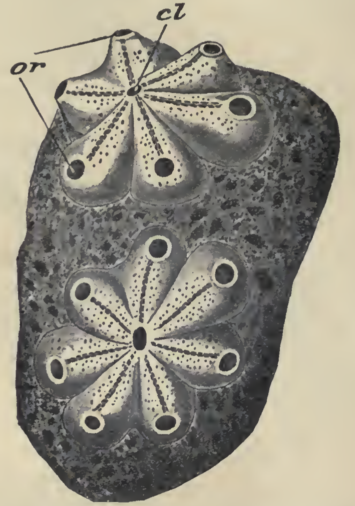

Fig. 202.—Botryllus violaceus. *or*, oral apertures; *cl*, opening of common cloacal chamber. (After Milne-Edwards.)

A number of other Urochorda are permanently free-swimming, but these are all almost, if not quite, as thoroughly metamorphosed as the Ascidians, so that their true affinities only become clear when their life-histories are followed.

3. THE VERTEBRATA

The Sub-phylum Vertebrata comprises the lancelets, the lampreys and their allies, the fishes, the amphibians, the reptiles, the birds, and the mammals. The lancelets occupy an extremely isolated position with regard to the other members of the sub-phylum, and are best regarded as constituting by themselves a division, which, for reasons which will be manifest shortly, is designated *Acrania*, the rest of the sub-phylum being known as *Craniata*.

A. *THE ACRANIA*

This isolated group, the Acrania, comprises only a single family, the two genera (*Branchiostoma* and *Asymmetron*) of which are distinguished from one another by comparatively slight differences.

Branchiostoma (more widely known under the name of **Amphioxus**), the lancelet, is a small transparent animal, occurring in the sea near the shore and burrowing in sand; its length does not exceed 5.8 cm. or less than two inches. Its form will be obvious from Fig. 203. The body is elongated, pointed at either end, and compressed. The anterior two-thirds is roughly triangular in transverse section, presenting right and left sides, inclined towards one another, above, and a convex ventral surface. The posterior third is nearly oval in section, the right and left sides meeting above and below in a somewhat sharp edge.

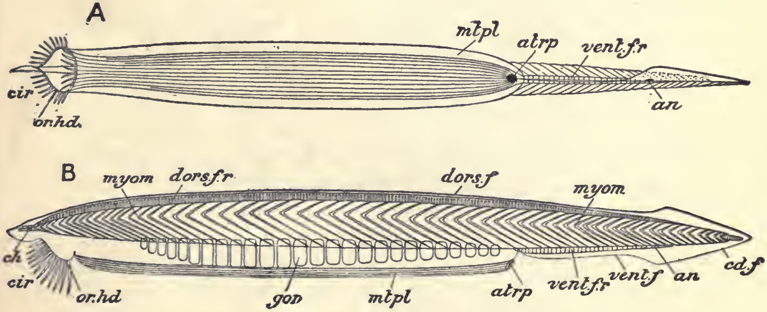

FIG. 203. — **Amphioxus lanceolatus**. A, ventral; B, side view of the entire animal. *an*, anus; *atrp*, atriopore; *cd. f*, caudal fin; *cir*, cirri; *dors. f*, dorsal fin; *dors. f. r.* dorsal fin-rays; *gon*, gonads; *mtpl*, metapleure; *myom*, myomeres; *nch*, notochord; *or. hd*, oral hood; *vent. f*, ventral fin; *vent. f. r*, ventral fin-rays. (After Kirkaldy.)

Extending along the whole of the dorsal border is a median longitudinal fold, the *dorsal fin* (*dors. f*); this is continued round the posterior end of the body and extends forwards, as the *ventral fin* (*vent. f*), as far as the spot where the oval gives place to the triangular transverse section. The portion of the continuous median fold which extends round the pointed posterior extremity of the body is somewhat wider than the rest, and may be distinguished as the *caudal fin* (*cd. f*). In the anterior two-thirds of the body there is no median ventral fin, but at the junction of each lateral with the ventral surface is a paired longitudinal fold, the *metapleure* (*mtpl*), which extends forward to the oral hood mentioned in the next paragraph.

Below the pointed anterior extremity is a large median aperture surrounded by a frill-like membrane, the *oral hood* (*or. hd*), the edge of which is beset with numerous tentacles or *cirri*. The oral hood encloses a cup-shaped cavity or *vestibule*, at the bottom of which is the *mouth* (Fig. 204, *mth*). Immediately in front of the anterior termination of the ventral fin and partly enclosed by the metapleures is a rounded aperture of considerable size, the *atripore* (*atrp*), and a short distance from the posterior extremity of the body is the *anus* (*an*), placed unsymmetrically on the left side of the ventral fin. The postanal portion of the body is distinguished as the *tail.*

Amphioxus ordinarily lives with the greater part of the body buried in sand, only the anterior end with the expanded oral hood protruding. It also swims in the vertical position, and frequently lies on one side on the sand; it burrows, head foremost, with great rapidity. It occurs on the American coast as far north as Cape Hatteras. A current of water is constantly passing in at the mouth and out at the atriopore.

The *muscular layer* (*my*) is remarkable for exhibiting metameric segmentation. It consists of a large number — about sixty — of muscle segments or *myomeres*, separated from one another by partitions of connective tissue, the *myocommas*, and having the appearance, in a surface view, of a series of very open V's with their apices directed forwards (Figs. 203 and 204).

The chief of the skeletal or supporting structures of the lancelet is the *notochord* (Figs. 203 and 204, *nch*), a cylindrical rod, pointed at both ends, and extending from the anterior to the posterior end of the body in the median plane. It lies immediately above the enteric tract and between the right and left myomeres. It is composed of a peculiar form of cellular tissue, known as *notochordal tissue*, formed of large vacuolated cells extending from side to side of the notochord, and having the nuclei confined to its dorsal and ventral regions. Around these cells is a *notochordal sheath* of connective tissue which is produced dorsally into a canal for the nervous system.

The oral hood is supported by a ring (Fig. 204, *sk*) of cartilaginous consistency, made up of separate rod-like pieces arranged end to end, and corresponding in number with the cirri.

The pharynx is supported by delicate oblique rods of a chitinoid material, the *gill-rods* (*br. r*). The dorsal fin is supported by a single series, and the ventral fin by a double series, of *fin rays* (*dors. f. r*), short rods of connective tissue.

The mouth (*mth*), as already mentioned, lies at the bottom of the vestibule or cavity of the oral hood (*or. hd*). It is a small circular aperture surrounded by a membrane, the *velum* (*vl*) acting as a sphincter, the free edge of which is produced into a number of *velar tentacles* (*vl. t*).

The mouth leads into the largest section of the enteric canal, the *pharynx* (*ph*), a high compressed chamber extending through the anterior half of the

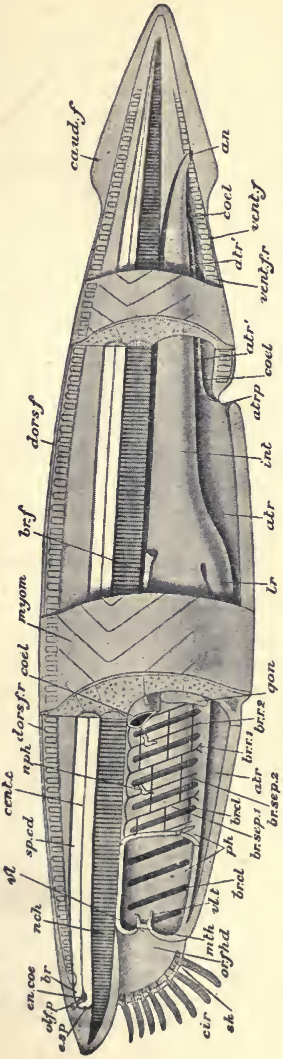

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FIG. 204.—Diagram of the anatomy of **Amphioxus**. *an*, anus; *atr*, atrium; *atr'*, its posterior prolongation: *atrp*, atriopore; *br*, brain; *br. cl*, branchial clefts; *br. f*, brown funnel; *br. sep.* 1, primary; *br. sep* 2, secondary branchial lamella; *br. r.* 1, primary; *br. r.* 2, secondary branchial rod; *caud. f*, caudal fin; *cent. c*, central canal; *cir*, cirri; *cæl*, cœlom; *dors. f*, dorsal fin; *dors. fr*, dorsal fin-ray; *en. cæ*, encephalocœle; *e. sp*, eye-spot; *gon*, gonad; *int*, intestine; *lr*, liver; *mth*, mouth; *myom*, myomeres; *nch*, notochord; *nph*, nephridia; *olf. p*, olfactory pit; *or. f. hd*, oral hood; *ph*, pharynx; *sk*, skeleton of oral hood and cirri (dotted); *sp. cd*, spinal cord; *vent. f*, ventral fin; *vent. f. r*, ventral fin-ray; *vel*, velum; *vl. t*, velar tentacles.

body. Its walls are perforated by more than a hundred pairs of narrow oblique clefts, the *gill-slits* or *branchial apertures* (*br. c*), which place the cavity of the pharynx in communication with the atrium (see below). From the posterior end of the pharynx goes off the tubular *intestine* (*int*) which extends backwards, almost in a straight line to the anus.

On the ventral wall of the pharynx is a longitudinal groove, the *endostyle*, lined by ciliated epithelium containing groups of gland-cells. Like the homologous organ in Ascidia (p. 317), the glands secrete a cord of mucus in which food particles are entangled and carried by the action of the cilia to the intestine. A somewhat similar structure, the *epipharyngeal groove*, extends along the dorsal aspect of the pharynx; its sides are formed by ciliated cells, which, at the anterior end of the groove, curve downwards, as the *peri-pharyngeal bands*, and join the anterior end of the endostyle.

From the ventral region of the anterior end of the intestine is given off a blind pouch, the *liver* (*lr*) or *hepatic cæcum*, which extends forwards to the right of the pharynx; it is lined with glandular epithelium and secretes a digestive fluid.

The *gill-slits* (*br. cl*) are long narrow clefts, nearly vertical in the expanded condition, but very oblique in preserved and contracted specimens — hence the fact that a large number of clefts always appear in a single transverse section (Fig. 205).

The *branchial septa* or lamellæ (Fig. 204, *br. sep*), or portions of the pharyngeal wall separating the clefts from one another, are covered by an epithelium composed, except on the outer face, of greatly elongated and ciliated cells. Each septum is supported towards its outer edge by one of the chitinoid *branchial rods* (*br. r*) already referred to.

The gill-clefts lead into a wide chamber occupying most of the space between the body-wall and the pharynx and called the *atrium* (Fig. 204, *atr*). It is crescentic in section, surrounding the ventral and lateral regions of the pharynx, but not its dorsal portion. It ends blindly in front; opens externally, behind the level of the pharynx, by the atriopore (*atrp*); and is continued backwards by a blind, pouch-like extension (*atr*) lying to the right of the intestine. As in Ascidia the cilia lining the gill-clefts produce a current setting in at the mouth, entering the pharynx, passing thence by the gill-slits into the atrium and out at the atriopore. The current, as in Tunicata and Balanoglossus, is both a respiratory and a food current, the animal feeding passively on the minute organisms in the surrounding water.

There is a system of blood-vessels, but no heart. A contractile median ventral vessel, the *ventral aorta*, runs forward in the ventral wall of the pharynx, and gives off lateral branches, the *afferent branchial* vessels, which pass upwards in the branchial lamellæ. Efferent branchial vessels receive the blood from the wall of the pharynx and open dorsally into a pair of longitudinal vessels, the *dorsal aortæ*. The latter join to form a median dorsal aorta, which runs backwards immediately below the notochord and above the intestine.

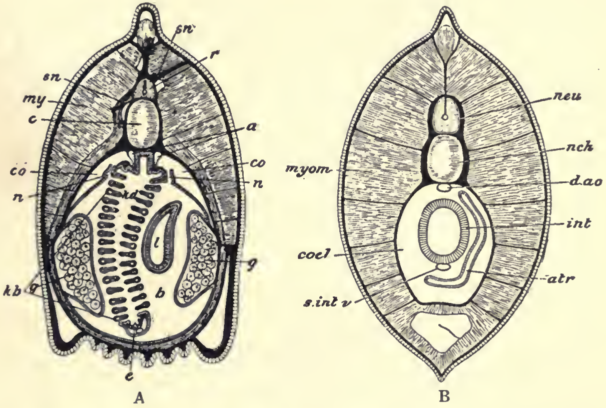

FIG. 205. — **Amphioxus lanceolatus**. A, transverse section of the pharyngeal region. *a*, dorsal aorta; *b*, atrium; *c*, notochord; *co*, cœlom; *e*, endostyle; *g*, gonad; *kb*, branchial lamellæ; *kd*, pharynx; *l*, liver; *my*, myomere; *n*, nephridium; *r*, neuron or dorsal nerve tube; *sn*, spinal nerves; *sp*, gill-slits. B, transverse section of the intestinal region; *atr*, atrium; *coel*, cœlom; *d. ao*, dorsal aorta: *int*, intestine; *myom*, myomere: *nch*, notochord: *neu*, neuron; *s. int. v*, subintestinal vein. (A, from Hertwig, after Lankester and Boveri; B, partly after Rolph.)

The principal *organs of excretion* are about ninety pairs of peculiarly modified *nephridia* (Fig. 204, *nph*) situated above the pharynx and in relation with the main cœlomic cavities.

An excretory function has also been assigned to a single pair of organs called the *brown funnels* (Fig. 204, *br. f*), also situated on the dorsal aspect of the pharynx at its posterior end.

The central nervous system is a rod-like organ, the *neuron* or *dorsal nerve-cord* (Fig. 204), contained within and completely filling a median longitudinal *neural canal* which lies immediately above the notochord. It is traversed by an axial canal, which becomes dilated at the anterior extremity. From this nerve-cord regularly arranged nerves are given off.

At the level of the anterior end of the nerve-cord is a narrow ciliated depression, the *olfactory pit* (Fig. 204, *olf. p*) opening externally on the left side of the snout and connected at its lower end with a median hollow process of the nerve-cord. This structure is supposed to be an organ of smell.

The organ of sight is an unpaired *pigment spot* (*e*) in the front wall of the brain; it is therefore a median *eye*. A peculiar structure, the *groove of Hatschek*, on the roof of the oral hood, is supposed to have a sensory function, and may be an organ of taste. Lastly, the sensory cells on the buccal cirri give those organs an important tactile function.

The sexes are separate, but there is no distinction, apart from the organs of reproduction, between male and female. The *gonads* (Fig. 204, *gon*) are about twenty-six pairs of pouches arranged metamerically along the body-wall and projecting into the atrium so as largely to fill up its cavity.

When ripe the inner walls of the gonadic pouches burst, and the ova or sperms make their way into the atrium and thence by the atriopore to the external water, where impregnation takes place.

B. *THE CRANIATA*

The fishes, amphibians, reptiles, birds, and mammals are grouped together under the general designation *Craniata*, derived from one of the features which these animals have in common, viz., the presence of a skull or *cranium*. In order to understand the general characteristics of the Craniata, it will be advisable to examine and compare representatives of some of the principal classes. For this purpose a dogfish, a lizard,[1] and a rabbit will be a good and convenient selection.

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[1] The anatomy of the *Anolis* or "American chameleon" of the Southern States is essentially like that of the European lizard.

Not only must entire and, if convenient, living specimens be examined, but prepared skeletons of all three must be available for examination, and preparations showing the various systems of internal organs, notably the digestive system, the heart, and the brain.

An external comparison appears at first sight to reveal few points of agreement between the three selected examples. The skin, the general shape, the movements, are all widely different. A few features common to all three are, however, to be recognised. It will be observed that in all three are distinguishable a *head region*, in front, a *trunk region* (by far the largest), in the middle, and a *tail region*, differing greatly in its development, behind. The head region bears anteriorly the opening of the mouth, bounded above and below by jaws

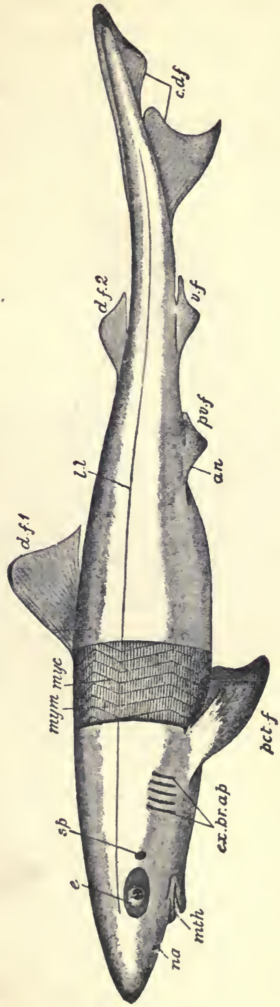

FIG. 206. — Side view of **Dogfish (Mustelus antarcticus)**, with a strip of skin in the middle of the body removed to show the muscles. *an*, anus; *c. d. f*, caudal fin; *d. f. 1*, *d. f. 2*, dorsal fins; *e*, eye; *ext. br. ap*, external branchial apertures; *l. l*, lateral line; *mth*, mouth; *myc*, myocommas; *mym*, myomeres; *n. a*, nasal aperture; *pct. f*, pectoral fin; *pv. f*, pelvic fin; *sp*, spiracle; *v. f*, ventral fin. (From Parker's *Biology*.)

bearing teeth; near the mouth are a pair of smaller apertures — the nostrils or nasal apertures, and at the sides of the head region are the pair of conspicuous eyes; while further back the pair of prominent auricles or pinnæ, with the wide apertures at their bases, mark very conspicuously the position of the auditory organs in the rabbit, less clearly indicated in the lizard, and still less in the dogfish. On the lower (ventral) surface, towards the posterior end of the trunk, will be observed in all three apertures which serve as the orifices through which the intestine and the ducts of the urinary and genital organs communicate with the exterior. A further resemblance

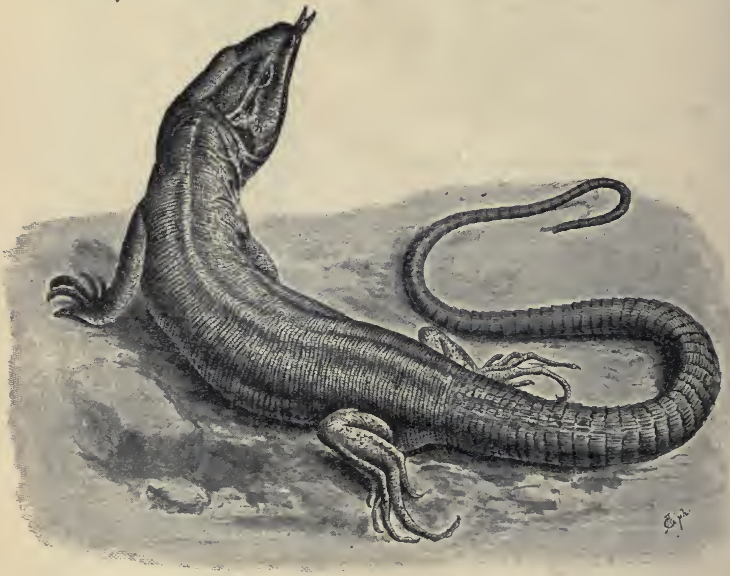

FIG. 207. — **Lacerta viridis.** (After Brehm.)

between the lizard and the rabbit consists in the presence of two pairs of jointed limbs, anterior and posterior, the principal divisions of which correspond in their general arrangement. In the dogfish these are found to be represented by very different-looking structures, the *paired fins*. At this point all external resemblance ceases, and we see nothing but differences.

The skin of the dogfish, though almost smooth, is harsh to the touch, and, when we examine it with a lens, this is found to be due to the presence of innumerable minute hard granules, set closely together so as to give the surface the character of a fine file. The general shape of the body is adapted to cleaving the water rapidly, — long and narrow, nearly fusiform, pointed at the ends, — and the fins are obviously swimming organs. The fins are all of the same general character, so far as their superficial appearance is concerned; they are all of the nature of flap-like outgrowths, thick at the base, where they are obviously supported by hard parts, thinner towards the margins, where their sole

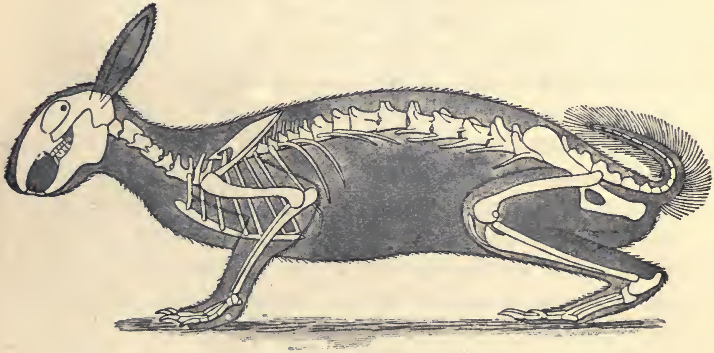

FIG. 208. — **Lepus cuniculus.** Lateral view of skeleton with outline of body.

support is a series of slender fibres of horny character. Besides the two pairs of fins which have already been referred to as taking the places of the anterior and posterior pairs of limbs in the lizard and rabbit, certain others are to be recognised which are of a totally different character, being *median* or *unpaired;* these, which are not in any way represented in either the lizard or the rabbit, are the two *dorsal*, the single *ventral*, and the single *caudal*, the last fringing the tail.

Behind the eye in the dogfish will be noticed a small aperture which seems to occupy very nearly the position occupied by the opening of the ear in the rabbit. This opening, however, the *spiracle*, does not lead into the ear, but into the cavity of the pharynx. Further back there are, on each side, five slit-like apertures in a row: these are the *branchial* or *gill-clefts*, and are not present in the lizard or the rabbit. In the living fish it will be observed that there are regular movements of the mouth, spiracles, and branchial clefts, indicating that water is being rhythmically taken in through the mouth and expelled by the spiracles and branchial clefts. Those are the movements of *respiration*.

The mouth is situated some little distance behind the anterior extremity of the head, on the ventral side. In front of it are the nasal openings (nostrils), which are also ventrally situated.

In the lizard the surface is covered with a system of overlapping horny scales. The head is separated from the trunk by a distinct constricted region, the *neck*. The tail is extremely long and narrow. The two pairs of limbs, anterior and posterior, or *pectoral* and *pelvic*, are adapted to running on the surface of the ground. Each consists of three divisions, — arm, fore-arm, and hand, — the anterior limb, thigh, leg, and foot in the posterior; and each hand and each foot contains five slender digits, each provided at its extremity with a curved and pointed horny claw. Slight rhythmical movements of dilatation and contraction of the anterior portion of the trunk are the movements of respiration, by means of which air is alternately drawn into and expelled from the lungs through the nostrils.

In the rabbit the place of the scales of the lizard is taken by the coating of hairs constituting the fur. The limbs present the same main divisions as in the lizard, though the proportions of the parts are very different, and the hind foot has only four toes. Between the head and trunk the neck region is more sharply marked off than in the lizard. Arising from the posterior part of the head, behind the eyes, are a pair of very prominent *auditory pinnæ* or *auricles*, at the base of each of which is the corresponding ear-opening. Movements of respiration resembling those of the lizard, but much more marked, are to be detected in the living animal.

When the skeletons of these three animals are examined and compared, it will be found that they are constructed on the same general plan with differences in details. In the dogfish it is mainly composed of cartilage; in the others, mainly of bone. In all there is a rod-like axis, the *spinal* or *vertebral column* supporting the trunk and tail, but not continued into the head, where its place is taken by the *skull*. The spinal column consists of a row of similar segments, the *vertebræ*, which articulate with one another. Each vertebra consists of a neutral solid portion, the *centrum* or body; an arch of bone or cartilage, the *neural arch*, situated on the dorsal side of the centrum, and certain processes. The series of centra form together a strong axial support for the entire body and tail; the series of neural arches enclose a canal, the *neural canal*, on the dorsal side of the centra. By the interlocking of certain processes — the *articulating processes* — of the neural arches the vertebræ in the lizard and rabbit are yet more firmly united together.

In the dogfish the centra have deeply concave anterior and posterior faces, so that when the vertebræ are in position there are hollows of considerable extent between the centra formed by the apposition of these concave faces. This form of centrum is termed *amphicœlous*. The entire spinal column is distinguishable into two regions, — the region of the *trunk* in front and the region of the *tail*

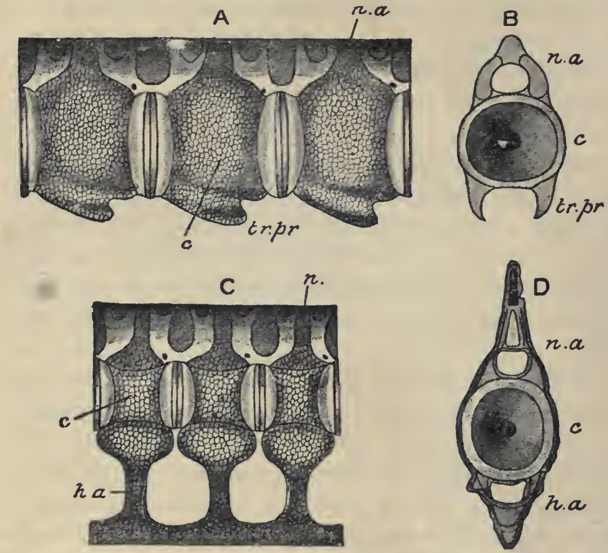

Fig. 209. — A, three trunk vertebræ of **Scyllium** from the side; B, a single trunk vertebra viewed from one end; C, three caudal vertebræ from the side; D, a single caudal vertebra from one end. *c*, centrum; *h. a*, hæmal arch; *n. a*, neural arch; *tr. pr*, transverse process. (After Hasse.)

behind. In the region of the trunk the vertebræ bear very small ribs in the form of short rods of cartilage; in the caudal region ribs are absent; but each vertebra bears, in addition to the neural arch, a ventrally situated arch of similar shape — the *hæmal arch*.

In both the lizard and the rabbit the vertebræ are composed entirely of bone. In the former the centra have concave anterior and convex posterior surfaces — and the vertebræ are accordingly said to be *procœlous*. In the latter the surfaces are flat, and the discs of fibro-cartilage, the *inter-vertebral discs*, are intercalated between the vertebræ.

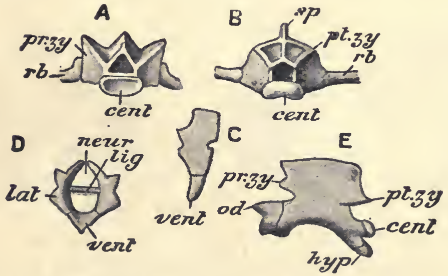

Fig. 210. — Vertebræ of **Lizard**. A, anterior, B, posterior, view of a thoracic vertebra; C, lateral, D, anterior, view of atlas vertebra; E, lateral view of axis. *cent*, centrum; *hyp*, hypapophysis of axis; *lat*, lateral piece of atlas; *lig*. ligamentous band dividing the ring of the atlas into two; *neur*, neural arch of atlas; *od*, odontoid process; *pr. zy*, pre-zygapophysis; *pt. zy*, post-zygapophysis; *rb*, rib; *sp*, spine; *vent*, ventral piece of atlas.

In both the spinal column is divisible into five regions, — the *cervical*, the *thoracic*, the *lumbar*, the *sacral*, and the *caudal*. The *cervical* region is the most anterior. In the rabbit the vertebræ of the cervical region are devoid of ribs; in the lizard they have short ribs with the exception of the first three. The first and second vertebræ in both the rabbit and the lizard are specially modified in connection with the movements of the head on the trunk. The vertebræ of the *thoracic* region are characterised by the possession of *ribs*, which, in the case of the most anterior, are connected with the breast-bone or *sternum* by slender cartilaginous *sternal ribs*. In the *lumbar* region there are no ribs. The *sacral* region is distinguished by its relations with the hind limb. The *caudal* region, short in the rabbit, very long in the lizard, lies behind the sacral. The ribs connected with the thoracic vertebræ are slender curved rods, which lie in the side walls of the anterior part of the trunk; the most anterior of them with their continuations, the sternal ribs, form half-loops extending from the spinal column dorsally to the sternum ventrally. The *sternum* or breast-bone, absent in the dogfish, lies in the middle of the wall of the ventral region of the trunk. In the lizard it is a rhomboidal plate of cartilage; in the rabbit it is bony, and divided up into a number of segments known as the *sternebræ*.

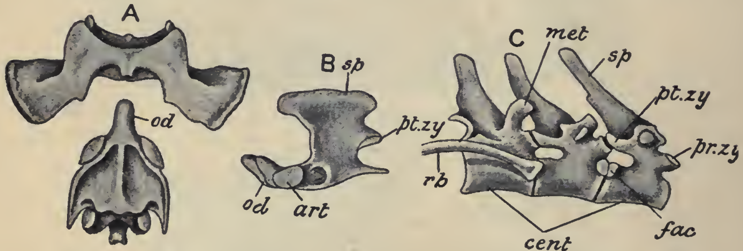

Fig. 211. – **Lepus cuniculus.** A, atlas and axis, ventral aspect; *od*, odontoid process of axis. B, lateral view of axis; *art*, articular facet for occipital condyle; *od*, odontoid process; *pt. zy*, post-zygapophysis; *sp*, neural spine. C, thoracic vertebræ, lateral view. *cent*, centrum; *fac*, facet for rib; *met*, metapophysis; *pr. zy*, pre-zygapophysis; *pt. zy*, post-zygapophysis; *rb*, rib; *sp*, spinous process.

In the embryo of each of the three forms used as illustrations, the spinal column passes through a stage in which it consists merely of a continuous cylindrical rod of cells — the *notochord*, corresponding to the notochord of Amphioxus — which becomes enclosed in a sheath. In some

Craniates it never passes beyond this stage, but remains of the nature of a *persistent notochord*, as it is termed. But in the great majority the notochord becomes enclosed in a sheath of cartilage, and thus becomes divided up into a number of segments. Eventually ossification sets in, and the series of completely formed bony vertebræ becomes developed.

As already mentioned, the spinal column does not extend into the head region. The skeleton of this region is the complex cartilaginous or bony structure known as the *skull.* The chief part of this is a case, the *cranium*, in the interior of which the brain is lodged, and the walls of which afford support to three pairs of organs of special sense,—the *nasal* or *olfactory organs* in front, the *eyes* in the middle, and the *ears* or *auditory organs* behind. The cavity of the cranium opens behind by a rounded foramen, the *foramen magnum*, into the anterior end of the neural canal enclosed by the neural arches of the vertebræ; and the posterior region of the cranium articulates movably with the first vertebræ of the spinal column. In addition to the cranium the skull or skeleton of the head comprises certain elements known as the *visceral arches.* The foremost of these forms the *jaws*, the second is the *hyoid*, and mainly supports the tongue, the remainder are the *branchial arches.*

In the dogfish the cranium remains in the primitive condition of a cartilaginous case, with complete walls and floor, but with the roof partly formed of fibrous membrane. In the lizard and rabbit the substance of the cartilage is replaced by a number of *cartilage bones*, *i.e*, bones which take the place of pre-existing cartilage, to which are superadded a number of *membrane bones*, *i.e.*, bones, the site of which was not preoccupied by cartilage; the whole united together so as to form a structure of considerable com-

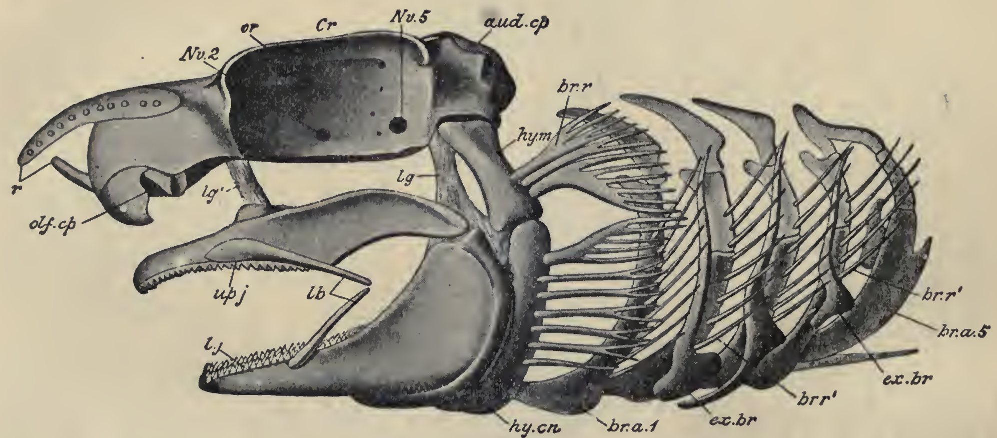

FIG. 212.—Side view of skull of **Scyllium canicula**. The cranium (*Cr*) shows the projecting auditory capsule (*aud. cp*), the hollow orbit (*or*), the olfactory capsule (*olf. cp*), and the cartilages of the rostrum or beak (*r*). In the orbit are seen apertures for the optic (*Nv. 2*) and trigeminal (*Nv. 5*) nerves. Articulated with the auditory capsule is the hyomandibular (*hy. m*), helping to support the upper (*up.j*) and lower (*l.j*) jaws, and giving attachment below to the hyoid cornu (*hy. cn*); the upper jaw is also attached to the cranium by two ligaments (*lg. lg'*) and small labial cartilages (*lb*) are connected with them. Following upon the hyoid cornu (*hy. cn*) come the five branchial arches (*br. a. 1-5*); from these, as well as from the hyomandibular and hyoid cornu, are given off branchial rays (*br. r*, *br. r'*), which are connected externally with extra-branchial cartilages (*ex. br*). (After W. K. Parker.)

plexity. The visceral arches in the dogfish are composed of a system of rods of cartilage. The first visceral arch forms the upper and lower jaws, between which the opening of the mouth is situated. The jaws are connected on each side with the skull behind by means of a cartilage known as the *hyomandibular*, which is a part of the second or hyoid arch; the rest of the hyoid arch and the branchial arches, which are five in number, lie in the lateral and ventral walls of the pharynx and support the gills.

In both the lizard and the rabbit the branchial arches are not present as such, the only well-developed visceral arches being the first and second. The upper jaw is formed of certain membrane bones, and in the lower jaw also the cartilage completely disappears, its place being taken by bones which are early completely united together, so as to form the bony lower jaw or *mandible*. In the lizard the mandible articulates on each side with the posterior region of the skull through the intermediation of a bone known as the *quadrate*, which is an element of the first visceral arch. In the rabbit the articulation between the mandible and the skull is direct, no quadrate intervening.

The skeleton of the limbs in the dogfish differs widely from that of the lizard and rabbit. In all three we distinguish the limb-arch from the skeleton of the free part of the limb itself. The limb-arch (pectoral or pelvic) is a cartilage or a system of bones with which the base of the free part of the limb articulates, and has the function of connecting the limb with the trunk and serving for the origin of many of the muscles moving the limb. In the dogfish the entire skeleton of the limbs is composed of cartilages which are so arranged as to support the thin broad expanse of the fin. In both the lizard and the

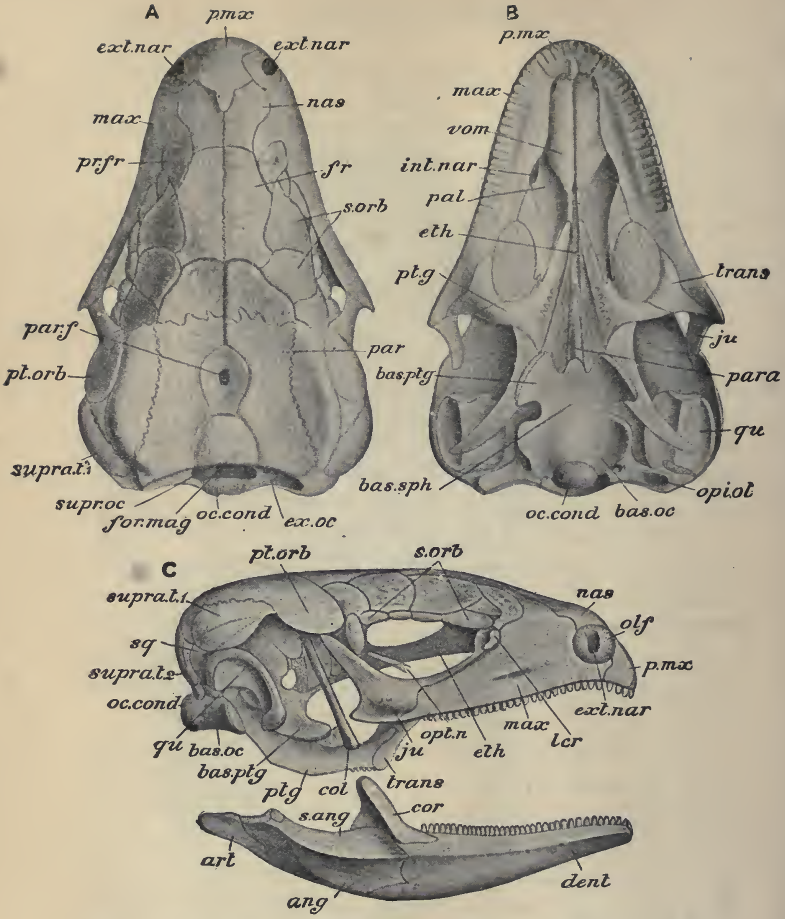
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FIG. 213. — Skull of **Lacerta agilis**. A, from above; B, from below; C, from the side. *ang*, angular: *art*, articular; *bas oc*, basi-occipital; *bas. ptg*, basi-pterygoid processes; *bas. sph*, basi-sphenoid; *col*, epi-pterygoid; *cor*, coronary; *dent*, dentary; *eth*, ethmoid: *ex oc*, ex-occipital: *ext. nar*, external nares; *for mag*, foramen magnum: *fr*, frontal; *int. nar*, internal nares; *ju*, jugal; *lcr*, lacyrmal; *max*, maxilla; *nas*, nasal; *oc. cond*, occipital condyle; *olf*, olfactory capsule; *op. ot*, opisthotic; *opt n*, optic nerve; *pal*, palatine; *par*, parietal; *par*. parasphenoid: *par. f*, parietal foramen; *p. mx*, pre-maxillæ; *pr. fr*, prefrontal; *ptg*, pterygoid, *pt. orb*, post orbital; *qu*, quadrate; *s. ang*, supra-angular; *s. orb*, supra-orbitals; *sq*, squamosal; *supra. t.*^{1}, supra-temporal 1; *supra t.*^{2}. supra-temporal 2; *trans*, transverse; *supra. oc*, supra-occipital; *vom*, vomer. (After W. K. Parker.)

rabbit the skeleton of the limbs is constructed on a general plan, common to the limbs of all Craniata but the fishes, and known as the *pentadactyle,* in allusion to the five digits in which the limb typically terminates. In the pectoral limb the upper arm has a single long bone known as the *humerus;* at its proximal end this is movably articulated with the pectoral arch. The forearm contains two long bones — *radius* and *ulna* — articulating proximally with the distal end of the humerus. The skeleton of the hand consists of three principal parts, — the *carpus,* the *metacarpus,*

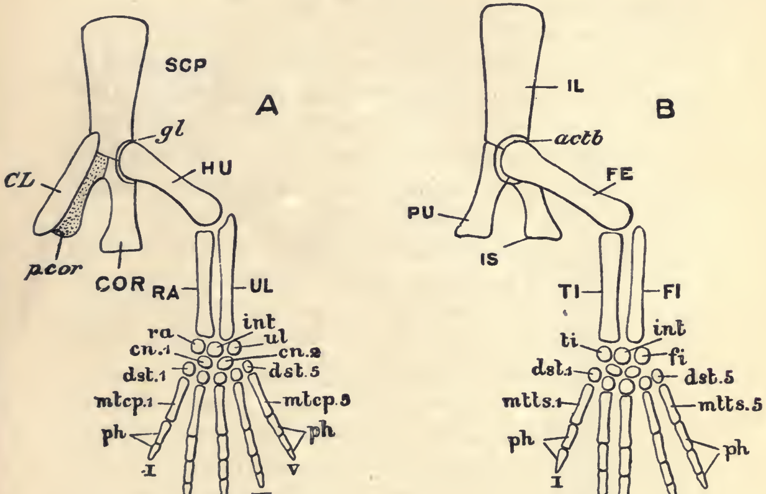
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FIG. 214. — Diagrams of the fore (A) and hind (B) limbs with the limb-girdles. *actb*, acetabulum; *gl*, glenoid cavity; *p. cor*, procoracoid; *I–V*, digits. Cartilage bones — **cn.1**, **cn.2**, centralia; **COR**, coracoid; **dst. 5–1**, distalia; **FE**, femur; **FI**, fibula; **fi**, fibulare; **HU**, humerus; **IL**, ilium; **int**, intermedium; **IS**, ischium; **mtcp. 1–5**, metacarpals; **mt. ts. 1–5**, metatarsals; **ph**, phalanges; **PU**, pubis; **RA**, radius; **ra**, radiale; **TI**, tibia; **ti**, tibiale; **UL**, ulna; **ul**, ulnare, membrane bone; *CL*, clavicle.

and the *phalanges*. The *carpus* or wrist consists of a number of small irregularly shaped bones arranged in two transverse rows, proximal and distal, with a central bone between the rows. The *metacarpus* consists of five narrow bones forming the support of the basal parts of the five digits, and articulating proximally with the distal row of carpals. The rest of the skeleton of the digit is formed of a row of small bones, the *phalanges*, the last of which — *ungual* phalanx — is modified in shape to support the horny claw.

The skeleton of the hind-limb corresponds closely with that of the fore-limb. The pelvic arch consists on each side of three bones which become firmly united together, one of these, the *ilium*, is dorsal in position, the other two, *pubis* and *ischium*, are ventral, the pubis being anterior to the ischium. The ilia articulate firmly with the sacral region of the spinal column; the pubes unite ventrally in an articulation known as the *pubic symphysis*, and in the lizard the ischia are similarly connected. Laterally where the three bones unite is a cup-like cavity — the *acetabulum* — which forms the socket for the head of the thigh-bone.

The thigh has a single long bone, the *femur*. The leg has two bones, the *tibia* and *fibula*, the former, which is internal, being the larger of the two, and the latter in the rabbit not being distinct from the former towards the distal end. In the foot are a number of *tarsal* bones corresponding to the carpals of the hand, a series of *metatarsals* corresponding to the metacarpals and a series of *phalanges*.

When the skin of the trunk of the dogfish is removed there will be found immediately beneath it a thick layer of *muscle*. This is distinctly divided into segments or *myomeres* similar to those of Amphioxus, and this, with the division of the vertebral column into segments or vertebræ (which, however, do not exactly correspond in arrangement with the myomeres), indicates that the body, like that of Nereis or an Arthropod, is metamerically segmented. In the lizard and rabbit the metamerism of the muscular system, though distinguishable at an early stage, becomes lost in the adult, and the muscles take on a much more complicated arrangement.

On the jaws are a series of teeth, the function of which is to seize the food, and in the rabbit cut it into fragments, and crush it into yet smaller particles, in order to prepare it for the process of digestion. In the dogfish the teeth are numerous and of uniform character throughout, small with sharp points directed backwards. At their bases they are fixed to the surface of the cartilage of the jaw by means of dense fibrous tissue. In the lizard the teeth are also of uniform character (*homodont dentition*). They are of a simple conical shape, and fixed to the bone of the jaws. In the rabbit the teeth are distinctly visible into sets, differing from one another in shape and function (*heterodont dentition*). Their bases are lodged in sockets or *alveoli* in the substance of the jaws.

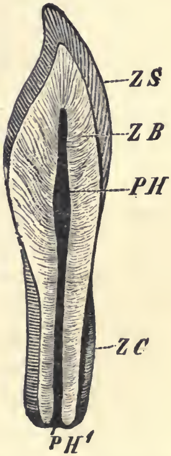

FIG. 215. — Longitudinal section of a tooth, semi-diagrammatic. *PH*, pulp cavity; *PH'*, opening of same; *ZB*, dentine; *ZC*, cement; *ZS*, enamel. (From Wiedersheim's *Vertebrata*.)

The structure of the tooth is the same in all three cases. The main mass of the tooth consists of *dentine*, a densely calcified material permeated by delicate parallel tubules. The free surface is covered with a layer of still harder material, the *enamel*, and the basal portion is covered with a layer of *cement*, which is similar in microscopic structure to bone.

The anterior part of the cavity into which the mouth leads is the *buccal cavity*, the posterior part is the *pharynx*. On the floor of the buccal cavity is, in the lizard and in the rabbit, a mobile muscular prominence, the *tongue*, represented in the dogfish by a much less prominent and little mobile process.

From this a wide tube leads backwards to open into a spacious chamber, the stomach. From the stomach the intestine, a more or less coiled tube, leads eventually to the anal aperture. In the dogfish and in the lizard the anus opens into a chamber, the *cloaca*, which also receives the ducts of the urinary and reproductive organs. In the rabbit a cloaca is absent, and the anus is separate from the urinogenital opening. The mucous membrane of the enteric canal contains numerous glands, the secretions of which play an important part in digestion; the most important of these secretions is the *gastric juice* secreted by the glands of the stomach. In addition, special large digestive glands are present producing secretions, also having the function of acting on the various components of the food in such a way as to facilitate the passage of the useful ingredients from the cavity of the alimentary canal to the blood-vessels. In the rabbit these special large digestive glands are the *salivary glands*, the *liver*, and the *pancreas;* in the dogfish and lizard the salivary glands are absent, though in the latter there are numerous small glands, the *buccal glands*, in the wall of the buccal cavity. The secretion of the salivary glands, the *saliva*, enters the cavity of the mouth through the ducts of the glands. It contains a ferment, *ptyalin*, which has the property of converting starch into sugar. The liver is in all three a relatively large organ, fixed by folds of peritoneum to the dorsal wall of the abdominal cavity and divided by fissures into a number of lobes. Its

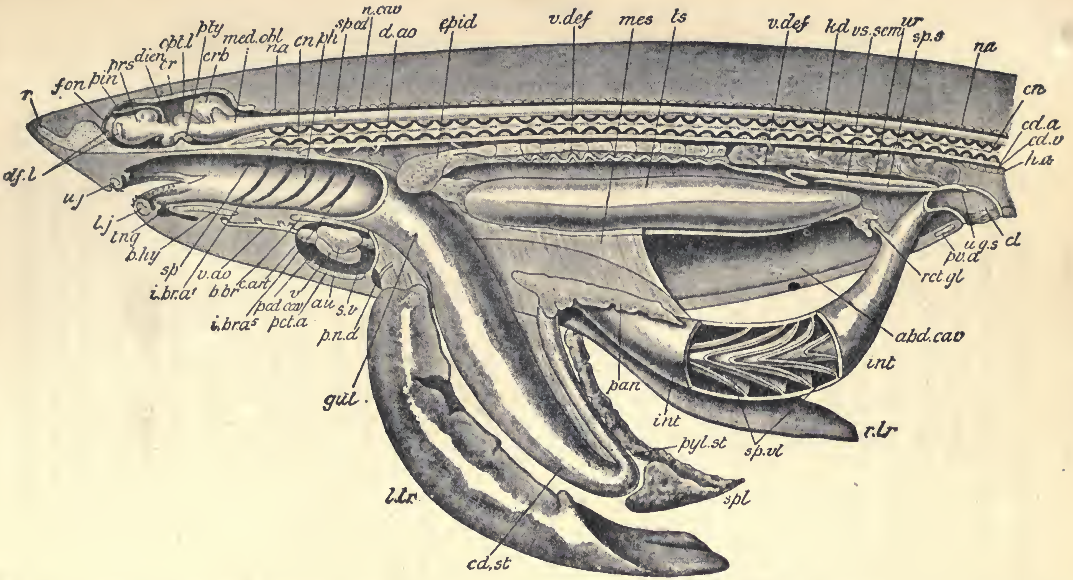
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Fig. 216. — Dissection of **Dogfish (Scyllium canicula)** from the left side. The left side of the body-wall is cut away in the median plane so as to expose the abdominal (*abd. cav*), pericardial (*pcd. cav*), and neural (*n. cav*) cavities in their whole length. The cartilage is dotted; the calcified ends of the vertebræ black. *au*, auricle; *b. br*, basi-branchial cartilage; *b. hy*, basi-hyal; *c. art*, conus arteriosus; *cd. st*, cardiac portion of stomach; *cd. v*, caudal vein; *cl.* cloaca; *cn*, centra; *cr*, cranium; *crb*, cerebellum; *d. ao*, dorsal aorta; *dien*, third ventricle; *epid*, epididymis; *fon*, fontanelle in roof of skull; *h. a*, hæmal arches; *i. br.* a^1, *i. br.* a^5, internal branchial apertures; *int*, intestine; *kd*, kidney; *l. j*, lower jaw; *l. lr*, left lobe of liver; *med. obl*, medulla oblongata; *n. a*, neural arches; *olf. l*, olfactory lobe; *opt. l*, optic lobe; *pan*, pancreas; *pct. a*, pectoral arch; *ph*, pharynx; *pin*, pineal body; *pr. s*, prosencephalon; *pty*, pituitary body; *pv. a*, pelvic arch; *r*, rostrum; *rct. gl*, rectal gland; *r. lr*, right lobe of liver; *sp*, spiracle; *sp. cd*, spinal cord; *spl*, spleen; *sp. s*, sperm sac; *vs. sem*, vesicula seminalis; *sp. vl*, spiral valve; *s. v*, sinus venosus; *tng*, tongue; *ts*, testis; *ug. s*, urogenital sinus; *u. j*, upper jaw; *ur*, ureter; *v*, ventricle; *v. ao*, ventral aorta; *v. def*, vas deferens.

duct, the *bile duct*, conveys its secretion, the *bile*, into the most anterior part of the intestine known as the *duodenum*. The duct gives off a diverticulum which expands into a rounded sac, the *gall-bladder;* this acts as a receptacle for the bile when it is not required. The bile has an important action on the fatty matters of the food, converting them into an *emulsion* and decomposing a small proportion into glycerine and fatty acid. In addition to secreting the bile the liver has another function to perform: it acts as a storehouse for surplus carbohydrates absorbed from the food. The carbohydrates — compounds of the nature of starch and sugar — are converted in the liver into a substance known as *glycogen* or animal starch, which becomes stored up in the cells to be given out again to the blood as it is required for nutrition during the intervals of fasting; this function of the liver is known as the *glycogenic function*.

The pancreas, which is a much smaller gland than the liver, produces a secretion, the *pancreatic juice*, which has the effect of converting starch into sugar, proteids into soluble modifications known as *peptones*, and of assisting in the emulsification of fats. The duct of the pancreas also opens into the duodenum. The nutrient matters of the food, rendered soluble by the action of the various digestive fluids, pass into the blood contained in the blood-vessels in the wall of the enteric canal, and are thus conveyed throughout the body to be distributed. The fatty matters, however, pass into a system of minute vessels — the *lacteals* — which ramify in the wall of the intestine. The lacteals are not blood-vessels, but belong to the *lymphatic vascular system* to be referred to presently. The lacteals combine together and in the rabbit open into a large trunk — the *thoracic duct* — by means of which the absorbed emulsion, or *chyle* as it is termed, is conveyed to one of the great veins.

The body-cavity in which the enteric canal and other organs are contained is lined with a membrane, the *peritoneum*. This is reflected over the surface of the contained structures, and folds of it serve to suspend the various organs and connect them together. The best developed of these folds is the *mesentery* (defective in the dogfish), by means of which the intestine is attached to the dorsal wall of the body-cavity.

The organs of respiration of the dogfish are *gills* adapted for receiving oxygen from the air dissolved in sea-water; those of the lizard and the rabbit are lungs adapted for breathing air directly. The movements of respiration have been already referred to. In the dogfish these movements have the effect of causing water to be taken in by the mouth, and to pass out from the pharynx to the exterior through the gill-slits. In passing out, the water flows over the gills, which are sets of vascular elevations on the walls of a series of five pairs of chambers—the *branchial sacs* opening internally into the pharynx, and externally communicating with the surrounding water through the branchial slits. In this way the needed oxygen is constantly being taken up, and the carbon dioxide given off. The walls of the branchial sacs are supported by the hyoid and branchial arches.

Inspiration and expiration of air in the lizard and rabbit take place through the nostrils. The nasal chambers into which the nostrils lead communicate internally with the mouth-cavity or the pharynx through a pair of apertures known as the *internal* or *posterior nares*. On the floor of the pharynx behind the root of the tongue is a slit-like aperture, the *glottis*, opening behind into a chamber known as the *larynx*, the wall of which is supported by cartilages. From the larynx the air passes backwards along a tube, the *trachea*, the wall of which is supported by numerous rings of cartilage. The trachea bifurcates when it enters the body-cavity, each of the two branches, or *bronchi* as they are termed, passing to the corresponding lung. In the lizard the lung is in essence a thin-walled sac with elastic walls. In the wall of the sac immediately outside, the delicate internal epithelium is a rich network of blood-vessels, into the blood contained in which oxygen from the air in the cavity of the lung readily passes, while the carbonic acid is at the same time given off. In the rabbit the lung is of much more complicated structure, but the essential relations are the same.

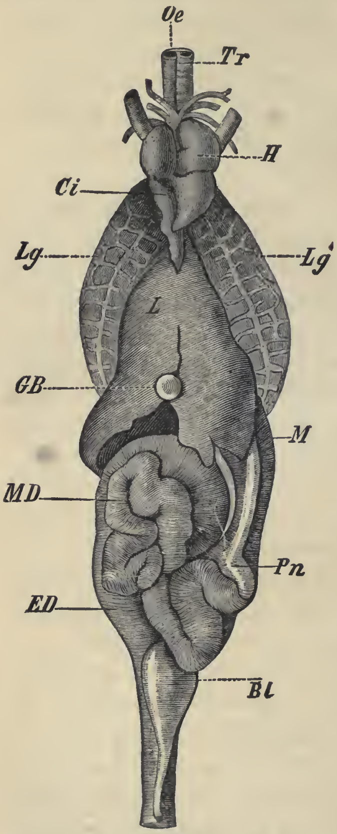

FIG. 217.—**Lacerta agilis.** General view of the viscera in their natural relations. *Bl*, urinary bladder; *Ci*, post-caval vein; *ED*, rectum; *GB*, gall-bladder; *H*, heart; *Lg*, *Lg'*, the lungs; *M*, stomach; *MD*, small intestine; *Oe*, œsophagus; *Pn*, pancreas; *Tr*, trachea. (After Wiedersheim.)

In the lizard the lungs lie in the anterior part of the general body-cavity. In the rabbit the anterior part of the body-cavity, containing the lungs and the heart, is separated off from the posterior part, containing the greater portion of the enteric canal and other organs, by a muscular partition concave posteriorly, — the *diaphragm*, — the anterior portion of the cavity being known as the cavity of the *thorax*, and the posterior as that of the *abdomen*.

The air in the lungs, as it is constantly losing oxygen and gaining carbon dioxide, requires to be frequently renewed; and the respiratory movements which have already been referred to are the movements indicative of this renewal; in the movement of *respiration* air is drawn into the lungs, which become fully distended; in that of *expiration*, the greater part of the air is driven out again, and the lung collapses. In the rabbit inspiration and expiration are effected by the movements of the ribs and of the diaphragm, by which the dimensions of the cavity of the thorax are increased or diminished.

The blood-vascular system is highly developed in all the three examples. The blood is of a red colour, owing to the presence of red corpuscles containing a red colouring matter termed *hæmoglobin*.

The blood-vessels are of three kinds, — *arteries*, *veins*, and *capillaries*. The arteries have firm and elastic walls, which do not collapse when the vessel is empty; they contain arterial blood, *i.e.*, blood which contains abundance of oxygen. The veins have thin, non-elastic walls which collapse when the vessel is empty and contain valves; the contained venous blood is darker in colour than the arterial, and has been deprived of oxygen in the tissues. Both arteries and veins ramify extensively, the ultimate branches being of very small size. Connecting together the ultimate branches of the arteries and the ultimate branches of the veins is a system of microscopic vessels — the *capillaries*.

The *heart* is ventral and anterior in position. In the dogfish it will be found to lie in a space, the *pericardial cavity*, between the two rows of gills, and separated behind from the general body-cavity (abdomen) in which the majority of the internal organs are contained, by a transverse fibrous partition. It consists of four chambers, — the *sinus venosus*, *auricle*, *ventricle*, and *conus arteriosus*. The venous blood enters the sinus venosus from the great veins and passes through the other three chambers in succession in the order given. All the chambers contract rhythmically, and by their contractions the blood is propelled from chamber to chamber, and finally driven out from the heart, its passage in the opposite direction being prevented by the presence of valves. These are placed in the openings leading from chamber to chamber, and are so arranged that while they permit the ready passage of the blood in the direction above given, they close up the opening when pressure is exerted in the opposite direction; thus, for example, when the auricle contracts, the valve guarding the opening leading back into the sinus venosus closes that opening, while the valve in the opening leading into the ventricle opens freely, and the blood passes readily in that direction. The ventricle is by far the most muscular of the four chambers, since it is mainly by its contractions that the blood is forced through the system of vessels. The blood which is forced out from the heart by the contractions of the ventricle passes into a series of vessels which carry it all to the gills. Here it enters a system of capillaries in the gills, and these being separated from the surrounding water only by a thin membrane, oxygen readily enters the blood, and the carbon dioxide collected in the various tissues and organs of the body is given off. The blood then enters a set of larger vessels, which combine to form a large trunk, the *dorsal aorta*. Branches from this distribute blood to all parts of the body, where it enters the systems of capillaries, and whence it is carried back again to the heart by the *veins*.

In the lizard the heart and the circulation are somewhat more complicated than in the dogfish. There is a sinus venosus as before. The auricle is completely divided into two chambers, right and left, by a partition. Into the right auricle the sinus venosus drives the venous blood from the great veins; into the left open the *pulmonary veins*, bringing the oxygenated blood from the lungs. Both the auricles open into the ventricle, the cavity of which is partly divided by a septum. From the ventricle are given off the main arteries (*systemic* arteries) which branch throughout all parts

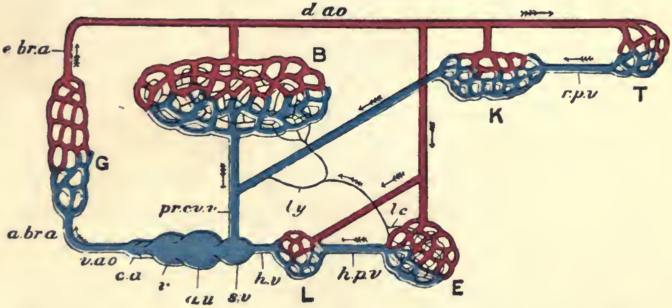

FIG. 218 — Diagram illustrating the course of the circulation in a fish. Vessels containing aërated blood, red; those containing non-aërated blood, blue; lymphatics, black. B, capillaries of the body generally; E, of the enteric canal; G, of the gills; K, of the kidneys; L. of the liver; T, of the tail. *a. br. a*, afferent branchial arteries; *au*, auricle; *c. a*, conus arteriosus; *d. ao*, dorsal aorta; *e. br. a*, afferent branchial arteries; *h. p v*, hepatic portal vein; *h. v*, hepatic vein; *lc*, lacteals; *ly*, lymphatics; *pr. cv. v*, pre-caval veins; *r. p. v*, renal portal veins; *s. v*, sinus venosus; *v*, ventricle; *v. ao*, ventral aorta. The arrows show the direction of the current.

of the body, and the *pulmonary* arteries, which pass direct to the lungs. By various arrangements of the parts which need not be described at present, the venous blood from the right auricle is mainly guided into the pulmonary arteries, and passes to the lungs to obtain oxygen and part with its carbon dioxide; while the arterial blood is mainly guided to the systemic arteries. A certain degree of mixing, however, of the venous and arterial currents takes place as they pass through the ventricle.

In the rabbit this mixing of the arterial and venous currents is entirely prevented, owing to the ventricle being completely divided into two chambers — right and left. The right auricle opens into the right ventricle, and fills it with venous blood from the great veins. From the right auricle the blood is driven through a *pulmonary artery* to the lungs. From the lungs the oxygenated blood is returned by means of the *pulmonary veins* to the left auricle ; from the left auricle it enters the left ventricle, and from the latter is driven out through the system of systemic arteries to all parts of the body. There are thus two distinct currents of blood constantly passing simultaneously through the heart, but entirely cut off from one another, viz., a *venous* current on the right side and an *arterial* on the left. The blood of the rabbit has a much higher temperature than that of the dogfish or lizard.

In all the three examples the veins which carry the venous blood towards the heart from the stomach, intestine, and pancreas unite together to form a large vein, the *hepatic portal*, which ramifies in the substance of the liver, and forms the main source of the blood supply of that organ. In the dogfish and lizard, but not in the rabbit, veins convey blood from the posterior region to the kidneys, forming what is termed a *renal* portal system.

The nervous system is highly developed. The central nervous system consists of the brain and spinal cord. The brain is, as already stated, contained in the cavity of the cranium ; the spinal cord, continuous with the posterior end of the brain, extends through the neural canal roofed over by the series of neural arches of the vertebræ.

The spinal cord is similar in essential respects in all three examples. It is a cylindrical cord of nerve matter, having running along the middle of its dorsal surface a fissure, the *dorsal longitudinal fissure*, and along the middle of its ventral surface, a second fissure, the *ventral longitudinal fissure.*

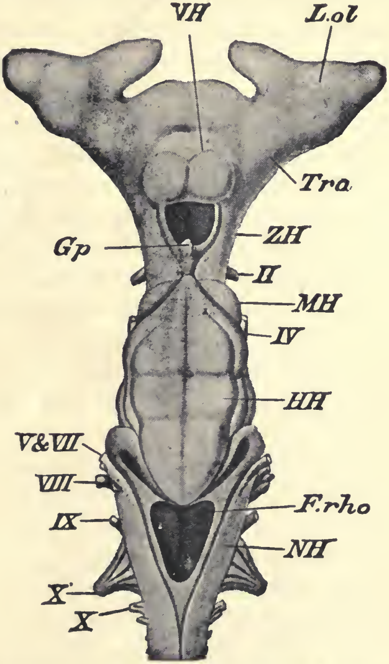

Fig. 219. — Dorsal view of the brain of **Scyllium canicula**. The posterior division of the brain is the medulla oblongata (*NH*), on the dorsal surface of which is shown one of the central ventricles (*F. rho*). The large cerebellum (*HH*) nearly covers the optic lobes (*MH*). The diencephalon (*ZH*) shows in the middle one of the central ventricles, and the place of attachment of the pineal body (*Gp*). The prosencephalon (*VH*) gives off the olfactory lobes (*Tro*, *L. ol*). The following nerves are shown: optic (*II*), trochlear (*IV*), trigeminal (*V*), facial (*VII*), auditory (*VIII*), glossopharyngeal (*IX*), and vagus (*X*). (From Wiedersheim.)

Through its substance from end to end runs a narrow canal, the *central canal.*

In the brain of the dogfish the most anterior portion is a thick mass of nerve matter indistinctly divided into two lateral portions by a shallow depression. This is the *prosencephalon* of the *fore-brain.* A pair of lobes given off from this in front are the *olfactory lobes.* The prosencephalon with a narrow region, *diencephalon* or *thalamencephalon,* behind it, constitute the *fore-brain.* Behind the fore-brain a pair of oval lobes, the *optic lobes,* constitute the dorsal portion of the *mid-brain,* which comprises, in addition, a thick mass of longitudinal nerve-fibres, lying below, and connecting the hind-brain with the fore-brain. An elongated median mass, indistinctly divided into lobes, is the *cerebellum,* the anterior portion of the hind-brain. The posterior division of the hind-brain, — *medulla oblongata,* — broad in front, tapers posteriorly where it passes into the spinal cord.

The central canal of the spinal cord expands in the medulla oblongata into a wide shallow cavity, roofed over only by a thin membrane; this is known as the *fourth ventricle.* From this runs forwards a narrow passage, the *iter* or *aqueduct* of *Sylvius,* expanding in front in the thalamencephalon into a laterally compressed cavity, the *third ventricle.* From this are given off a pair of *lateral ventricles,* passing into the prosencephalon, each giving off a prolongation into the corresponding olfactory tube.

The roof of the third ventricle is very thin; it is produced into a slender process — the *epiphysis* or *pineal body.* Its side walls are formed of two masses, the *optic thalami;* its floor is produced into a hollow prolongation, the *infundibulum,* to the end of which a vascular body, the *hypophysis* or *pituitary body* is applied.

In the brain of the lizard the same parts are recognisable as in the dogfish, the chief differences being that the prosencephalon is deeply divided by a median longitudinal fissure into two lobes, the *cerebral hemispheres*, and that the cerebellum is very small. In the rabbit also we recognise the same parts. But the whole brain is larger in proportion to the bulk of the body; the cerebral hemispheres are much more highly developed, and the cerebellum is not only of large relative size, but is of complicated structure.

The peripheral nervous system consists of the spinal and cerebral nerves given off from the spinal cord and the brain respectively, with their ramifications through all parts of the body. A pair of spinal nerves emerge from the neural canal between each adjoining pair of vertebræ. Each spinal nerve arises from the spinal cord by two roots — a dorsal and a ventral; the former is dilated into a ganglion. Experiments prove that the dorsal root contains the *sensory* fibres of the nerves, *i.e.*, those fibres which are concerned in carrying impulses from the various parts to the nerve centres to be translated in consciousness into sensations. When, for example, the skin of some part of the body is touched, the impulse by means of which we become conscious of the contact passes from the surface through branches of the spinal nerves, and enters the spinal cord through the dorsal root, in order to be transmitted to the brain. The ventral root, on the other hand, contains the motor fibres; the fibres through which impulses which lead to the contraction of muscles pass outwards from the central nervous system.

More or less extensive intercommunications take place between the spinal nerves that are situated opposite the origin of the limbs; these *spinal nerve plexuses* give off the nerves to the limbs.

The *cerebral* or *cranial nerves* correspond pretty closely in their general arrangement in the three examples. The *olfactory* nerve-fibres, which originate from the olfactory lobes, the *optic* nerves, which are derived from the thalamencephalon, and the *auditory* nerves which originate from the medulla oblongata, are the nerves of the special senses of smell, sight, and hearing respectively, the first ending in the epithelium of the nasal cavities, the second in the retina of the eye, and the third in the epithelium of the interior of the inner ear. Other cranial nerves supply the muscles that move the eyeball, the skin of the head, the muscles of the jaws, the tongue, pharynx, heart, stomach, etc.

The structure of the *eye* is in all essential respects the same in all the three examples; such differences as there are will be referred to later. The eye of a bullock or a sheep, being larger, may with advantage be substituted. The eyeball is globular, and is encased in a rough opaque capsule, the *sclerotic*. It lies in the cavity of the orbit, and is capable of being turned about in various directions by a number of muscles inserted into it. On the side of the eyeball directed towards the light, the opaque sclerotic is replaced by a transparent membrane, the *cornea*, which forms a window through which the rays of light enter the eye. Within the sclerotic is a more delicate pigmented layer, the *choroid*. Towards the cornea the choroid passes into a circular pigmented diaphram, the *iris*, the opening of which is known as the *pupil*. Through the pupil, the size of which is capable of being increased or diminished, the light is admitted into the interior of the eye. The sensitive part of the eye, the part on which the image produced by the rays of light proceeding from an object must fall in order to produce the sensation of sight, is a soft gray layer lining that part of the cavity of the eye which lies within the iris. The rays of light are brought to a focus on the retina mainly by means of the *crystalline lens*, a firm, glassy body situated within the iris. The cornea also assists in this, as does a gelatinous substance, the *vitreous humour*, which fills the part of the cavity of the eyeball internal to the lens.

The ear in the dogfish is imbedded in the cartilage of the posterior part of the skull (auditory region). It consists of a somewhat complicated structure termed the *membranous labyrinth*, with soft walls and an internal epithelium in which the fibres of the auditory nerve terminate. Contained in the interior of the labyrinth is a fluid, the *endolymph*, in which there are suspended particles of

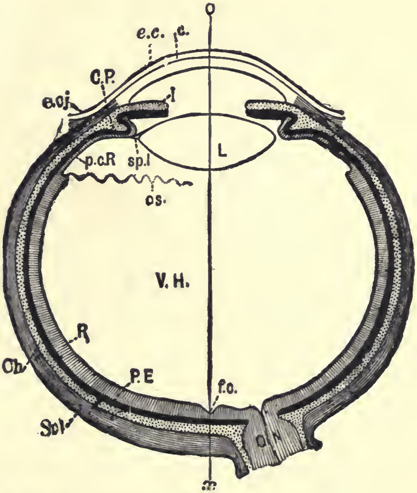

FIG. 220. — Diagrammatic horizontal section of the eye of man. *c*, cornea; *ch.* choroid (dotted); *C. P*, ciliary processes; *e. c*, epithelium of cornea; *e. cj*, conjunctiva; *f. c*, yellow spot; *I*, iris; *L*, lens; *ON*, optic nerve; *OS*, ora serrata; *o–x*, optic axis; *p. c. R*, anterior non-visual portion of retina; *P. E*, pigmented epithelium (black); *R*, retina; *sp. l*, suspensory ligament; *Scl*, sclerotic; *V. H*, vitreous body. (From Foster and Shore's *Physiology*.)

carbonate of lime, the *otoliths*. In the lizard and rabbit there are superadded to this, the essential part of the ear, certain accessory parts. The most important of these is the *tympanum* or drum of the ear. This is a cavity to the outside of the auditory region of the skull (the region in which the membranous labyrinth is enclosed). The tympanum communicates with the pharynx through a passage known as the *Eustachian passage*. Externally the cavity of the tympanum is closed by a tense, drum-like membrane, the *tympanic* membrane. The tympanic membrane is set in vibration by the waves of sound, and the vibrations are transmitted across the tympanic cavity by a slender rod of bone (in the lizard) or a chain of minute bones (in the rabbit). The inner end of the rod or chain of bones is inserted into a membrane covering over a small aperture in the outer wall of the auditory region of the skull, which forms the inner wall of the tympanic cavity, and by this means the vibrations are communicated to the endolymph of the membranous labyrinth and affect the terminations of the auditory nerve-fibres. In the lizard the tympanic membrane is nearly on a level with the skin of the head, and its position is conspicuously indicated by a brown patch situated behind the eye. In the rabbit the tympanic membrane is more deeply sunk, and a wide passage, the passage of the outer ear, leads to it from the exterior. The ear of the rabbit also differs from that of the lizard in the presence of the prominent auricle or pinna of the ear to which reference has been already made.

The *kidneys*, or organs of renal excretion, though they differ in form in the three examples are not widely different in essential structure. Their function is the secretion of *urine*, which consists of water containing various nitrogenous waste matters in solution. Essentially the kidney is a mass of tubules by whose agency the process of secretion is carried on, the whole being richly supplied with blood-vessels. Eventually the tubules open into a duct, the *ureter*. In the lizard and the rabbit there is present a median thin-walled sac, the *urinary bladder*, in which the urine is stored, to be discharged at intervals. In the rabbit the ureters open into the bladder, and the latter opens on the exterior by a median canal, the *urethra*. In the lizard the ureters and the bladder have independent openings into the cloaca, and the bladder is filled only by regurgitation from the latter chamber.

The *sexes* are distinct in all three. There are two *testes*, each with its duct or *vas deferens*. In the female there are two *ovaries*, which are solid bodies in which the ova lie imbedded. In the dogfish, when mature, the ova are of large size, containing a great quantity of food-yolk. The ova of the rabbit are extremely small, while those of the lizard are of a size intermediate between those of the other two. Each ovum is enclosed in a follicle — the *Graafian follicle* — with a wall composed of small cells. When the ovum approaches maturity the follicle projects on the surface of the ovary, and eventually the wall becomes ruptured and the ovum escapes into the body-cavity.

The *oviducts*, of which there are two, are not connected with the ovaries, each opening anteriorly into the body-cavity by a wide opening. In the dogfish and the lizard the oviducts remain practically distinct from one another throughout; in the rabbit the posterior parts are united to form a median chamber, the body of the *uterus*, and a median passage, the *vagina*, leading to the exterior. The ova in all three, when discharged from the ovaries, enter the wide openings of the oviducts and are impregnated during their passage backwards. In both the dogfish and the lizard each fertilised ovum becomes enclosed while in the oviduct in a tough *shell*, and is discharged when development has only begun. In the rabbit the fertilised ovum is received into the uterus and there undergoes its development, the young rabbit when born differing little, save in size, from the adult. The nourishment of the *fœtus* or uterine young of the rabbit is effected by means of a special vascular structure known as the *placenta*, by means of which nutrient material passes from the blood of the mother to that of the fœtus; and after birth the young rabbit receives its nourishment for a time exclusively from the secretion of a set of glands of the mother — the *mammary* or *milk glands*.

CLASS I. CYCLOSTOMI

The lowest of existing Craniate Vertebrates are certain fish-like animals known as "lampreys" and "hag-fishes," or "slime-fishes," which are looked upon as constituting the class of Craniata, to which the name of Cyclostomi is applied. Of them it is here possible only to make the briefest mention. The lampreys (*Petromyzon* and other genera) and the hag-fishes or slime-fishes (*Myxine* and *Bdellostoma*) are somewhat eel-like in general shape, that is to say, they have a long and narrow body without marked external distinction into regions, and with a soft and slimy integument. Of the fins of such a fish as the dogfish the median or unpaired series alone are represented, paired fins corresponding to the limbs of the higher Craniata being entirely absent. There is a dorsal fin divided into two in the lampreys, undivided in the hag-fishes, which is continued as a tail fin round the posterior or caudal extremity of the body. On the lower or ventral surface of the anterior or head-end is a deep hollow — the buccal funnel, much more conspicuous in the lampreys than in the hags, at the bottom of which the small opening of the mouth is situated. There are no jaws, but on the inner surface of the buccal funnel and on the tongue — a fleshy (?) process below the opening of the mouth. In Myxine the funnel is edged with slender, flexible processes or tentacles. At the sides of the head are the eyes, well developed and conspicuous in the lamprey, imperfect and buried beneath the skin in Myxine, and on the upper surface is a single median aperture, the nostril. Further back at the sides of the head are, in the lamprey, a series of seven pairs of slits, the gill-slits, leading to the gill-pouches; in Bdellostoma there are six pairs of small gill-slits, in Myxine only a single aperture on each side.

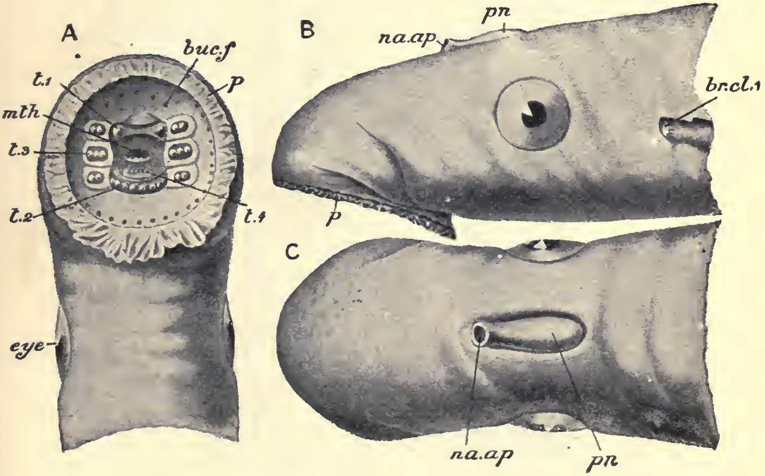

Fig. 221. — **Petromyzon marinus.** Ventral (A), lateral (B), and dorsal (C) views of the head. *br. cl. 1*, first gill-cleft; *buc. f*, buccal funnel; *eye*, eye; *mth*, mouth; *na. ap*, nasal aperture; *p*, papillæ: *pn*, pineal area; *t. 1*, *t. 2*, *t. 3*, teeth of buccal funnel; *t. 4*, teeth of tongue. (After W. K. Parker.)

The skeleton is very unlike that of the true fishes, and is in some respects extremely primitive. The spinal column is represented merely by a thick persistent notochord, enclosed in a sheath, with, in the lampreys, small cartilaginous processes representing neural and hæmal arches. The skull is cartilaginous, and is peculiarly modified. Behind it in the lamprey is a remarkable basket-like apparatus,

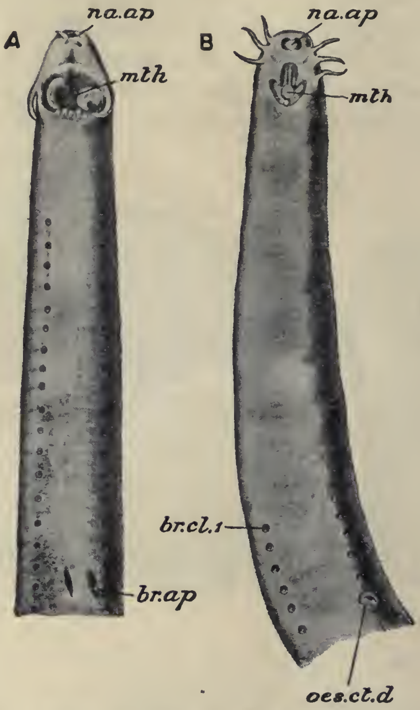

FIG. 222. — Head of **Myxine glutinosa** (A) and of **Bdellostoma forsteri** (B), from beneath. *br. ap*, branchial aperture; *br. cl. 1*, first branchial cleft; *mth*, mouth; *na. ap*, nasal aperture; *oes. ct. d*, œsophageo-cutaneous duct. The smaller openings in A are those of the mucous glands. (After W. K. Parker.)

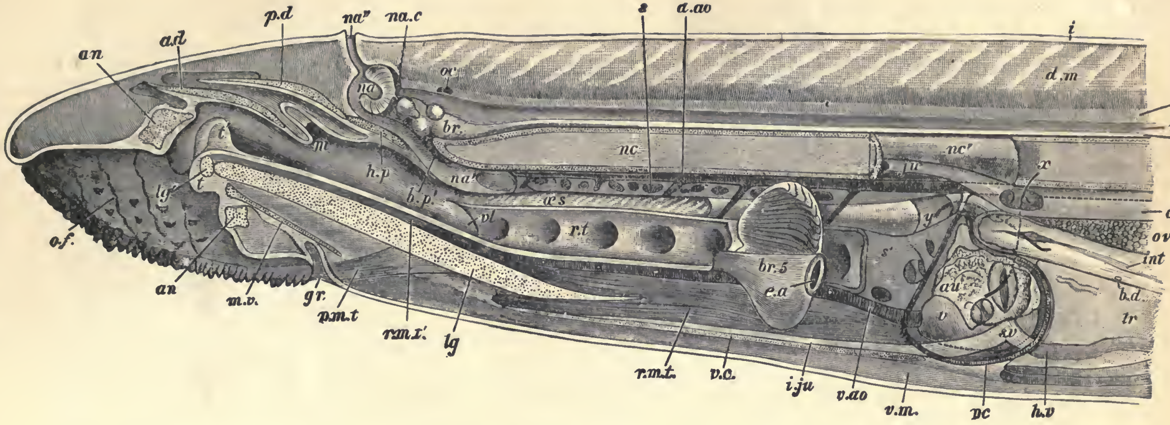

FIG. 223.—**Petromyzon marinus.** Dissection of female. The cartilaginous parts and the sheath of the notochord are dotted. *a. d*, anterior dorsal cartilage; *an*, annular cartilage; *au*, auricle, opened to show auriculo-ventricular aperture below and the sinu-auricular above; *b. d*, aperture of bile-duct (abnormal); *b. p'*, portion of basal plate behind basi-cranial fontanelle; *br*, brain: *br. 5*, fifth left gill-sac, the upper half cut open; *cd*, left cardinal vein; *d. ao*, dorsal aorta; *d. m*, dorsal muscles; *e. a*, external aperture of fifth gill-sac; *f. t*, fibrous tissue of neural canal; *gr*, groove below buccal funnel; *h. p*, portion of basal plate anterior to basi-cranial fontanelle; *h. v*, hepatic vein; *i*, integument; *i. ju*, inferior jugular vein; *int*, intestine; *ju*, jugular vein: *lg*, lingual cartilage: *lg'*, small cartilage attached to lingual; *lr*, liver; *m*, buccal cavity; *mv*, median ventral cartilage; *my*, spinal cord; *na*, olfactory sac; *na'*, pituitary pouch; *na''*, nasal aperture; *na. c*, nasal capsule; *nc*, *nc*^{1}, notochord; *n. ca*, spinal canal; *oc*, cranial roof; *æs*, gullet; *o. f*, buccal funnel; *ov*, ovary; *pc*, pericardium; *p. d*, posterior dorsal cartilage; *p. m. t*, protractor muscle of tongue; *r. m. t*, retractor of tongue; *r. m. t'*, its tendon; *r. t*, respiratory tube; *s. s'*, lymph sinus surrounding gullet; *s. v*, sinus venosus; *t, t'*, tongue; *v*, ventricle; *v. ao*, ventral aorta; *v. c*, ventral longitudinal bar of branchial basket; *vl*, velum; *v. m*, ventral muscles; *x*, bristle passed from cardinal vein through sinus venosus into auricle; *y*, bristle passed from gullet into intestine. (From Parker's *Zootomy*.)

composed of cartilaginous processes. This branchial basket, as it is termed, supports the gill-sacs.

The gill-sacs, of which there are either six or seven pairs, are the organs of respiration, representing the gills of the true fishes. In the lamprey each of these communicates with the exterior by the corresponding gill-slit, and internally opens into a common passage, the respiratory tube which leads in front into the buccal cavity. In Bdellostoma each gill-pouch has its own internal opening through a narrow tube into the pharynx, as well as its external opening through a small gill-slit. In Myxine, on the other hand, though each pouch has a separate internal communication with the pharynx, the tubes leading outwards from the gill-pouches of each side all join to form a common tube, which opens on the exterior by the single gill-slit.

The other systems of organs are not so remarkable. The alimentary canal, the heart, and the brain are not widely different from those of the true fishes. A peculiar feature is that there is only a single nasal sac (opening by the single nasal aperture already referred to) instead of the pair developed in all other Craniates; in Myxine its cavity communicates by a passage with the cavity of the mouth. In the lamprey, in addition to paired eyes having the typical vertebrate structure, there is connected with a lobe in the roof of the fore-brain a *median* or *pineal eye* of simpler structure and imperfectly understood function.

Lampreys live mainly in rivers and estuaries. Their food consists chiefly of small aquatic animals, such as worms, small crustaceans, etc.; but they also sometimes attach themselves to the bodies of fishes, by means of the sucker-like buccal funnel, and rasp off portions of the flesh with the horny teeth of the tongue. Myxine actually makes its way into the interior of the bodies of large fishes, such as the cod, consuming the flesh in its passage, and thus becomes for a time an internal parasite — the only example among the Vertebrata of such a condition. In the free state Myxine usually lies buried in the sand, with only the anterior end, with the nasal aperture, projecting on the surface. By means of the passage leading from the nasal sac to the mouth, water passes in and out through the nasal aperture, and the process of respiration is carried on while the animal remains almost completely hidden.

The geographical distribution of the Cyclostomi is somewhat remarkable. *Petromyzon* is found on the coasts and in the rivers of Europe, North America, Japan, and West Africa. Of the allied genera one, *Ichthyomyzon*, occurs on the western coast of North America; another, *Mordacia*, in Tasmania and Chili; a third, *Geotria*, in the rivers of Chili, Australia, and New Zealand. Myxine occurs in the North Atlantic and on the Pacific Coast of South America, including the Straits of Magellan; Bdellostoma on the coasts of South Africa, New Zealand, and Chili.

CLASS II. PISCES

The class Pisces or Fishes includes the **Elasmobranchii** or cartilaginous fishes (sharks, dogfishes, and rays), the **Teleostomi** or bony fishes (such as perch, pike, mackerel, cod, sole, salmon, sturgeon, and bony pike), and the **Dipnoi** or lung-fishes. In these the organs both of respiration and of locomotion are adapted for an aquatic mode of life. The chief and, in the majority, the only organs of respiration are the gills, which are in the form of series of vascular processes attached to the branchial arches and persisting throughout life. The organs of locomotion are the paired pectoral and the pelvic fins, and the unpaired dorsal, ventral, and caudal; these are all supported by fin-rays of dermal (p. 372) origin. A hard external covering of scales developed in the dermis is usually present. In the endoskeleton the notochord is usually replaced more or less completely by cartilaginous or bony vertebræ; there is a well-developed skull and a system of well-formed visceral arches, of which the first forms the upper and lower jaws, the latter movably articulating with the skull, and both nearly always bearing teeth. An air-bladder is frequently present, and in certain exceptional cases acquires the function of a lung or chamber for breathing air.

Sub-class I. Elasmobranchii

A dogfish may be selected as a convenient example of the sub-class and of the class Pisces. Dogfishes occur at slight depths off the coasts in all quarters of the globe. The commonest European forms are the rough hound (*Scyllium canicula*), the lesser spotted dogfish (*S. catulus*), the piked dogfish (*Acanthias vulgaris*), and the smooth hound (*Mustelus vulgaris*). Allied species of the southern hemisphere are *Scyllium*, *Acanthias*, and *Mustelus anarcticus*. On the coast of Northeastern America the common dogfish is *Mustelus canis*. For the description which follows, any of these species will be found to serve very well.

A slight general account of the dogfish has already been given in the introduction to the Craniata; this has now to be extended and supplemented. The general shape (Fig. 206) may be described as fusiform; at the anterior or head-end it is broad and depressed; posteriorly it tapers gradually and is compressed from side to side. The head terminates anteriorly in a short blunt snout. The tail is narrow and bent upwards towards the extremity. The entire surface is covered closely with very minute hard *placoid scales* or *dermal teeth* somewhat larger on the upper surface than on the lower. These are pointed, with the points directed somewhat backwards, so that the surface appears rougher when the hand is passed over it forwards than when it is passed in the opposite direction. When examined closely, each scale is found to be a minute spine situated on a broader base. The spine consists of dentine covered with a layer of enamel; the base is composed of bone, and the whole scale has thus the same essential structure as a tooth. Along each side of the head and body runs a faint depressed longitudinal line or slight narrow groove, — the *lateral line.*

As in fishes in general, two sets of fins are to be recognised, — the *unpaired* or *median* fins, and the *paired* or *lateral.* These are all flap-like outgrowths, running vertically and longitudinally in the case of the median fins, nearly horizontally in the case of the lateral; they are flexible, but stiffish, particularly towards the base, owing to the presence of a supporting framework of cartilage. Of the median fins, two — the *dorsal* — are situated, as the name indicates, on the dorsal surface: they are of triangular shape; the anterior, which is the larger, is situated at about the middle of the length of the body, the other a little further back. The *caudal* fringes the tail; it consists of a narrower dorsal portion and a broader ventral, continuous with one another round the extremity of the tail, the latter divided by a notch into a larger, anterior, and a smaller, posterior lobe. The tail is *heterocercal, i.e.*, the posterior extremity of the spinal column is bent upwards and lies in the dorsal portion of the caudal fin. The *ventral* or so-called *anal* fin is situated on the ventral surface, opposite the interval between the anterior and posterior dorsals; it resembles the latter in size and shape.

Of the *lateral fins* there are two pairs, the pectoral and the pelvic. The *pectoral* are situated at the sides of the body, just behind the head. The *pelvic*, which are the smaller, are placed on the ventral surface, close together, in front of the middle of the body. In the males the bases of the pelvic fins are united together in the middle line, and each has connected with it a *clasper* or *copulatory organ*. The latter is a stiff rod, on the inner and dorsal aspect of which is a groove leading forwards into a pouch-like depression in the base of the fin.

The *mouth* — a transverse, somewhat crescentic opening — is situated on the ventral surface of the head, near its anterior end. In front and behind it is bounded by the upper and lower jaws, each bearing several rows of teeth with sharp points directed backwards. The nostrils are situated one in front of each angle of the mouth, with which each is connected by a wide groove, the *nasobuccal groove*. A small rounded aperture, the *spiracle*, — placed just behind the eye, — leads into the large mouth-cavity or pharynx. Five pairs of slits running vertically on each side of the neck, the *branchial slits*, also lead internally into the mouth-cavity. A large median opening on the ventral surface at the root of the tail, between the pelvic fins, is the opening leading into the cloaca, or chamber forming the common outlet for the intestine and the renal and reproductive organs. A pair of small depressions, the *abdominal pores*, situated behind the cloacal opening, lead into narrow passages opening into the abdominal cavity.

The **skeleton** is composed entirely of cartilage, with, in certain places, depositions of calcareous salts. As in Vertebrates in general, we distinguish two sets of elements in the skeleton, — the axial set and the appendicular, the former comprising the skull and spinal column, the latter the limbs and their arches.

The *spinal column* is distinguishable into two regions,—the region of the trunk and the region of the tail. In the trunk region each vertebra (Fig. 209, *A*) consists of a centrum (*c*), neural arch (*na*), and transverse processes (*tr. pr*). In the caudal region there are no transverse processes, but *inferior* or *hæmal arches* (*D, h. a*) take their place. The centra of all the vertebræ are deeply biconcave or *amphicœlous*, having deep conical concavities on their anterior and posterior surfaces. Through the series of centra runs the notochord, greatly constricted in the centrum itself, dilated in the large spaces formed by the apposition of the amphicœlous centra of adjoining vertebræ. The concave anterior and posterior surfaces of the centra are covered by a dense calcified layer, and eight radiating lamellæ of calcified material run longitudinally through the substance of the centrum itself. Each neural arch consists of a pair of rod-like *neural processes*, which form the sides, and two pairs of compressed *neural plates* (one placed opposite the centrum, the other or *intercalary cartilage*, opposite the interval between adjoining centra), which form the roof of the arch, together with usually two nodules — the representatives of *neural spines* — which form the keystones. The transverse processes are very short: connected with each of them is a cartilaginous rudimentary *rib* about half an inch in length.

The *cranium* (Fig. 224) is a cartilaginous case, the wall of which is continuous throughout, and not composed, like the skulls of higher vertebrates, of a number of distinct elements (bones) fitting in together. At the anterior end is a *rostrum*, consisting of three cartilaginous rods converging as they extend forwards and meeting at their anterior ends. At the sides of the base of this are the *olfactory capsules* (*olf. cp*),—thin rounded cartilaginous sacs opening widely below, — the cavities of the two capsules being separated from one another by a thin septum. The part of the roof of the cranial cavity behind and between the olfactory capsules is formed, not of cartilage, but of a tough fibrous membrane, and the space thus filled in is termed the *anterior fontanelle;* in contact with the lower surface of the membrane is the pineal body, to be afterwards mentioned in the account of the brain. Each side wall of this part of the skull presents a deep concavity, the *orbit* over which is a ridge-like prominence, the *supra-orbital crest,* terminating anteriorly and posteriorly in obscure processes termed respectively the *pre-orbital* and *post-orbital processes.* Below the orbit is a longitudinal *infra-orbital* ridge.

Behind the orbit is the *auditory region* of the skull (*aud. cp*), a mass of cartilage in which the parts of the membranous labyrinth of the internal ear are embedded. On the upper surface of this posterior portion of the skull are two small apertures situated in a mesial depression. These are the openings of the *aqueductus vestibuli* (*endolymphatic ducts*), leading into the vestibule of the membranous labyrinth. Behind this again is the *occipital region,* forming the posterior boundary of the cranial cavity, and having in the middle a large rounded aperture, the *foramen magnum,* through which the spinal cord contained in the neural canal and protected by the neural arches of the vertebræ becomes continuous with the brain, lodged in the cranial cavity. On either side of this is an articular surface, the *occipital condyle,* for articulation with the spinal column.

A number of smaller apertures or *foramina,* chiefly for the passage of nerves, perforate the wall of the skull.

In close connection with the cranium are a number of cartilages composing the *visceral arches* (Fig. 224). These are incomplete hoops of cartilage, mostly segmented, which

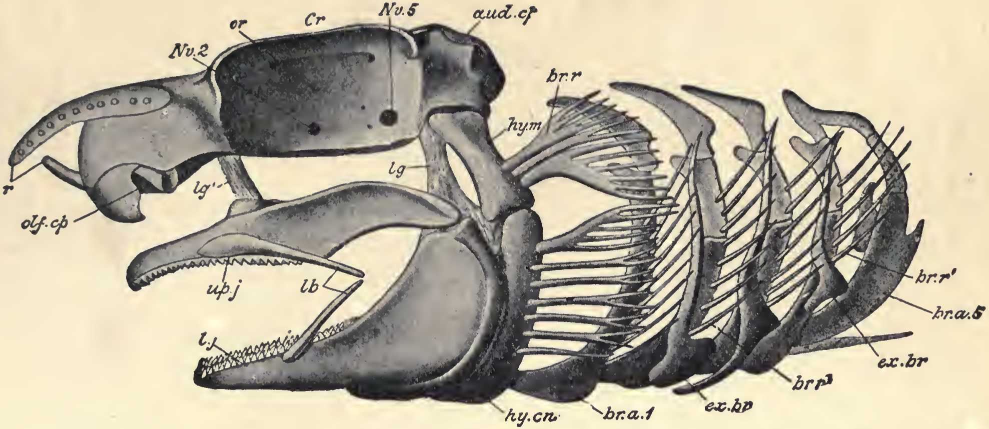

FIG. 224.—Side view of skull of **Scyllium canicula**. The cranium (*Cr*) shows the projecting auditory capsule (*aud. cp*), the hollow orbit (*or*), the olfactory capsule (*olf. cp*), and the cartilages of the rostrum or beak (*r*). In the orbit are seen apertures for the optic (*Nv. 2*) and trigeminal (*Nv.* 5) nerves. Articulated with the auditory capsule is the hyomandibular (*hy. m*), helping to support the upper (*up. j*) and lower (*l. j*) jaws, and giving attachment below to the hyoid cornu (*hy. cn*); the upper jaw is also attached to the cranium by two ligaments (*lg, lg'*) and small labial cartilages (*lb*) are connected with them. Following upon the hyoid cornu (*hy. cn*) come the five branchial arches (*br. a. 1–5*); from these, as well as from the hyomandibular and hyoid cornu, are given off branchial rays (*br. r, br. r'*), which are connected externally with extra-branchial cartilages (*ex. br*). (After W. K. Parker.)

lie in the sides and floor of the mouth-cavity or pharynx. The first of these forms the upper and lower jaws. The upper jaw, or *palato-quadrate* (*up. j*), consists of two stout rods of cartilage firmly bound together in the middle line and bearing the upper (or anterior) series of teeth. The lower jaw, or *Meckel's cartilage* (*l. j*), likewise consists of two stout cartilaginous rods firmly united together in the middle line, the union being termed the *symphysis*. At their outer ends the upper and lower jaws articulate with one another by a movable joint. In front the upper jaw is connected by a ligament with the base of the skull.

Immediately behind the lower jaw is the *hyoid arch*. This consists of two cartilages on each side, and a mesial one in the middle below. The uppermost cartilage is the *hyo-mandibular* (*hy. m*); this articulates by its proximal end with a distinct articular facet on the auditory region of the skull; distally it is connected by ligamentous fibres with the outer ends of the palato-quadrate and Meckel's cartilage. The lower lateral cartilage is the *cerato-hyal* (*hy. cn*). Both the hyo-mandibular and cerato-hyal bear a number of slender cartilaginous rods — the branchial rays of the hyoid arch (*br. r*). The mesial element, or *basi-hyal*, lies in the floor of the pharynx. Behind the hyoid arch follow the *branchial arches*, which are five in number. Each branchial arch consists of several cartilages and bears branchial rays.

The skeleton of all the fins — paired and unpaired — presents a considerable degree of uniformity. The main part of the expanse of the fin is supported by a series of flattened segmented rods, the *pterygiophores* or cartilaginous fin-rays, which lie in close apposition; in the case of the dorsal fins these are calcified along their axes. At the outer ends of these are one or more rows of polygonal plates of cartilage. On each side of the rays and polygonal cartilages are a number of slender horny fibres of dermal origin. In the smaller median fins there may be an elongated rod of cartilage constituting the skeleton, or cartilage may be entirely absent. In the pectoral fin (Fig. 225) the fin-rays are supported on three *basal cartilages* articulating with the *pectoral arch*. The latter is a strong hoop of cartilage incomplete dorsally, situated immediately behind the last of the branchial arches. It consists of a dorsal, or *scapular*, (*pct. g*) and a ventral, or *coracoid*, portion (*pct. g'*), the coracoid portions of opposite sides being completely continuous across the middle line, while the scapular are separated by a wide gap in which the spinal column lies. Between the two portions are the three articular surfaces for the three basal cartilages. The three basal cartilages of

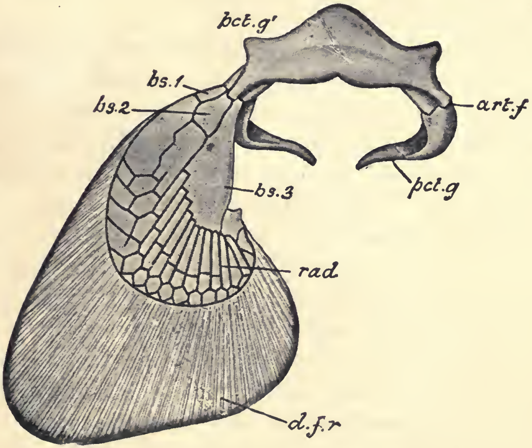

FIG 225. — Ventral view of pectoral arch of **Scyllium** with right pectoral fin. The pectoral arch is divisible into dorsal (*pct. g*) and ventral (*pct. g'*) portions, separated by the articular facets (*art. f*) for the fin. The pectoral fin is formed of three basal cartilages (*bs. 1–3*) and numerous radials (*rad*); its free edge is supported by dermal rays (*d. f. r*). (Modified from Marshall and Hurst.)

the fin are named, respectively, the anterior, *pro-pterygium* (*bs. 1*), the middle, *meso-pterygium* (*bs. 2*), and the posterior, *meta-pterygium* (*bs. 3*). Of these the first is the smallest, and the last the largest. The *pelvic fin* has only a single basal cartilage, articulating with the *pelvic arch*, with which also one or two of the fin-rays articulate directly. The pelvic arch is a nearly straight bar of cartilage which runs transversely across the ventral surface of the body, just in front of the cloacal opening.

The mouth leads into a very wide cavity, the *pharynx* (Fig. 216, *ph*), into which opens at the sides the internal apertures of the branchial clefts and of the spiracle. From this runs backwards a short wide tube, the *œsophagus* (*gul*), which passes behind into the stomach. The stomach is a U-shaped organ, with a long left limb (*cd. st*) continuous with the œsophagus, and a short right (*pyl. st*) passing into the intestine. At the *pylorus* — the point where the stomach passes into the intestine — is a slight constriction followed by a thickening. The *intestine* consists of two parts, — *small intestine* or *duodenum*, and *large intestine*. The former is very short, only an inch or two in length. The latter (*int*) is longer and very wide; it is divisible into two portions, — the *colon* in front and the *rectum* behind. The former is very wide and is characterised by the presence in its interior of a *spiral valve*, a fold of the mucous membrane which runs spirally round its interior and both retards the too rapid passage of the food, and affords a more extensive surface for absorption. The rectum differs from the colon in being narrower and in the absence of the spiral valve; it opens behind into the cloaca.

There is a large *liver* (*l. lr*, *r. lr*) consisting of two elongated lobes. A rounded sac, the *gall-bladder*, lies embedded in the left lobe at its anterior end. The duct of the liver, the *bile duct*, runs from the liver to the intestine. Proximally it is connected with the gall-bladder and by branch ducts with the right and left lobes of the liver. It opens into the commencement of the colon.

The *pancreas* (*pan*) is a light-coloured compressed gland consisting of two main lobes with a broad connecting isthmus lying in the angle between the right-hand limb of the stomach and the small intestine. Its duct enters the wall of the small intestine and runs in it for about half an inch, opening eventually at the point where the small intestine passes into the colon.

Connected with the rectum on its dorsal aspect is an oval gland, the *rectal gland* (*rct. gl*), about three-quarters of an inch in length.

The *spleen* (*spl*) is a dark-red or purple body attached to the convexity of the U-shaped stomach, and sending a narrow lobe along the right-hand limb.

The organs of respiration in the dogfish are the *gills*, situated in the five *gill-pouches*. Each gill-pouch is an antero-posteriorly compressed cavity opening internally into the pharynx and externally by the gill-slit. The walls of the pouches are supported by the branchial and hyoid arches with their rays, the first pouch being situated between the hyoid and first branchial arches, the last between the fourth and fifth branchial arches. On the anterior and posterior walls of the pouches are the *gills*, each hemibranch consisting of a series of close-set parallel folds or plaits of highly vascular mucous membrane. Separating adjoining gill-pouches and supporting the gills are a series of broad *interbranchial septa*, each containing the corresponding branchial arch with its connected branchial rays. The most anterior hemibranch is borne on the posterior surface of the hyoid arch. The last gill-pouch differs from the rest in having gill-plaits on its

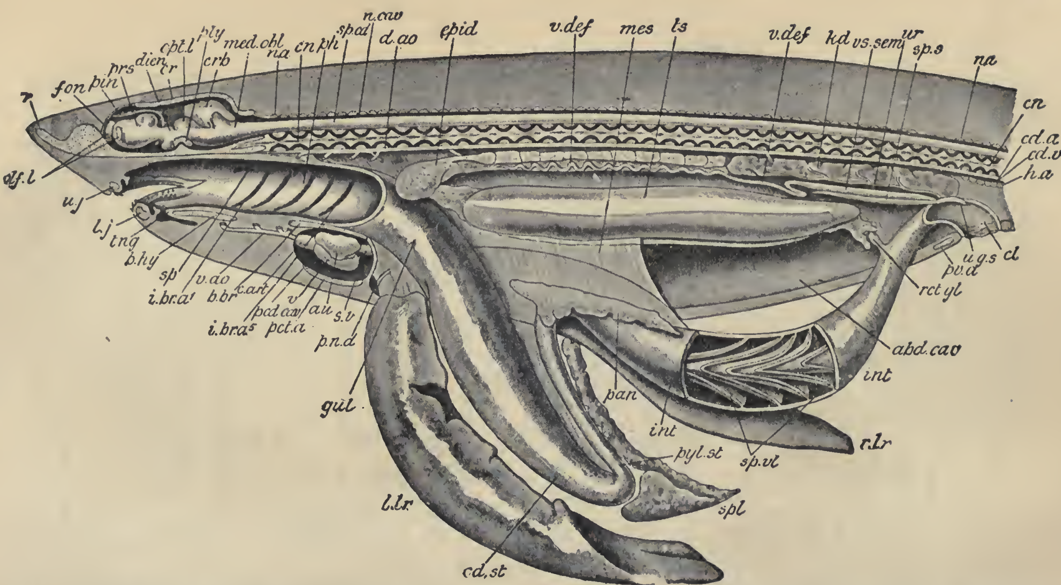
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FIG. 226. — Dissection of dogfish (**Scyllium canicula**) from the left side. The left side of the body-wall is cut away in the median plane so as to expose the abdominal (*abd. cav*), pericardial (*pcd. cav*), and neural (*n. cav*) cavities in their whole length. The cartilage is dotted; the calcified ends of the vertebræ black. *au*, auricle; *b. br*, basi-branchial cartilage; *b. hy*, basi-hyal; *c. art*, conus arteriosus; *cd. st*, cardiac portion of stomach; *cd. v*, caudal vein; *cl*, cloaca; *cn*, centra; *cr*, cranium; *crb*, cerebellum; *d. ao*, dorsal aorta; *dien*, third ventricle; *epid*, epididymis; *fon*, fontanelle in roof of skull; *h. a*, hæmal arches; *i. br. a*¹, *i. br. a*⁵, internal branchial apertures; *int*, intestine; *kd*, kidney; *l. j*, lower jaw; *l. lr*, left lobe of liver; *med. obl*, medulla oblongata; *n. a*, neural arches; *olf. l*, olfactory lobe; *opt. l*, optic lobe; *pan*, pancreas; *pct. a*, pectoral arch; *ph*, pharynx; *pin*, pineal body; *pr. s*, prosencephalon; *pty*, pituitary body; *pv. a*, pelvic arch; *r*, rostrum; *rct. gl*, rectal gland; *r. lr*, right lobe of liver; *sp*, spiracle; *sp. cd*, spinal cord; *spl*, spleen; *sp. s*, sperm sac; *vs. sem*, vesicula seminalis; *sp. vl*, spiral valve; *s. v*, sinus venosus; *tng*, tongue; *ts*, testis; *ug. s*, urogenital sinus; *u. j*, upper jaw; *ur*, ureter; *v*, ventricle; *v. ao*, ventral aorta; *v. def*, vas deferens.

anterior wall only. On the anterior wall of the spiracle is a rudimentary gill, the *pseudo-branch* or *spiracular gill,* in the form of a few slight ridges.

The *heart* is situated in the pericardial cavity, on the ventral aspect of the body, in front of the pectoral arch and between the two series of branchial pouches. The heart consists of four chambers, — *sinus venosus* (*s. v*), *auricle* (*au*), *ventricle* (*v*), and *conus arteriosus* (*c. art*), through which the blood passes in the order given. The *sinus venosus* is a thin-walled, transverse, tubular chamber, into the ends of which the great veins open. It opens into the auricle by an aperture, the *sinu-auricular* aperture. The *auricle* is a large, triangular, thin-walled chamber, situated in front of the sinus venosus and dorsal to the ventricle. Its apex is directed forwards, and its lateral angles project at the sides of the ventricle; it communicates with the ventricle by a slit-like aperture guarded by a two-lipped valve. The *ventricle* is a thick-walled, globular chamber, forming the most conspicuous part of the heart when looked at from the ventral surface. From it the *conus arteriosus* runs forwards as a medium stout tube to the anterior end of the pericardial cavity, where it gives off the *ventral aorta.* It contains two transverse rows of valves, anterior and posterior, the former consisting of three, the latter of three or four. The *ventral aorta* (Fig. 227, *v. ao*) gives origin to a series of paired *afferent branchial arteries* (*a. br. a*), one for each branchial pouch.

From the gills the blood passes by means of the *efferent branchial arteries* (*e. br. a*). These efferent vessels form a series of loops, one running around the margin of each of the first four internal branchial clefts: a single vessel runs along the interior border of the fifth branchial cleft and opens into the fourth loop. The four main efferent bran-

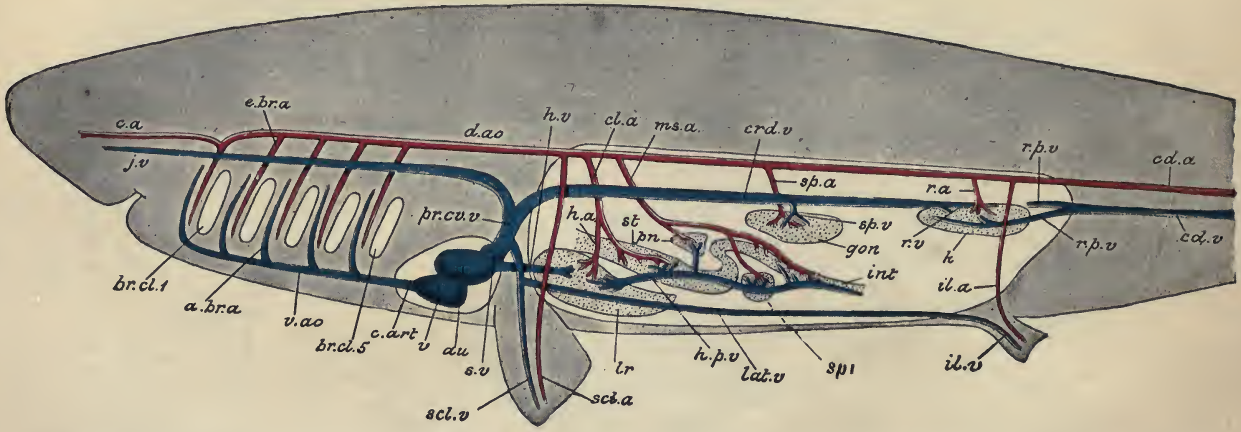
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FIG. 227. Diagram of the vascular system of a fish Vessels containing aërated blood red, those containing non-aërated blood blue. *a. br. a*, afferent branchial artery; *au*, auricle; *br cl. 1–5*, branchial clefts; *c. a*, carotid artery; *c art*, conus arteriosus; *cd. a*, caudal artery; *cd. v*. caudal vein; *cl. a*, cœliac artery: *crd v*, cardinal vein: *d. ao*, dorsal aorta; *e. br. a*, efferent branchial artery; *gon*, gonad; *h. a*, hepatic artery; *h. p v*, hepatic portal vein; *h. v*, hepatic vein; *il. a*, iliac artery; *il. v*, iliac vein; *int*, intestine; *j. v*, jugular vein; *k*, kidney; *lr*, liver: *lat. v*, lateral vein; *ms. a*, mesenteric artery; *pn*, pancreas; *pr cv v*, pre-caval vein; *r. a*, renal artery; *r. p. v*, renal portal vein; *r v*, renal vein; *scl. a*, subclavian artery; *scl v*, subclavian vein; *sp. a* spermatic artery; *spl*, spleen; *sp. v*, spermatic vein; *st*, stomach; *s. v*, sinus venosus; *v*, ventricle; *v ao*, ventral aorta.

chial vessels run inwards and backwards from the loops under cover of the mucous membrane of the roof of the mouth to unite in a large median trunk — the *dorsal aorta* (*d. ao*). From the first efferent vessel, that from the first or hyoidean gill, arises the *carotid artery*, which runs forwards and bifurcates to form the *internal* and *external carotid arteries* (*c. a*), supplying the head with arterial blood.

The *dorsal aorta* runs backwards throughout the length of the body-cavity, giving off numerous branches, and is continued as the *caudal artery* (*cd. a*), which runs in the canal enclosed by the inferior arches of the caudal vertebræ.

The *veins* are very thin-walled, and the larger trunks are remarkable for their dilated character, from which they have obtained the name of *sinuses*, though they are true vessels and not sinuses in the sense in which the word is used in dealing with the Invertebrates.

The venous blood is brought back from the head by a pair of *jugular* or *anterior cardinal sinuses* (*j. v*), and from the trunk by a pair of *posterior cardinal sinuses* (*crd. v*). At the level of the sinus venosus the anterior and posterior cardinals of each side unite to form a short, nearly transverse sinus, the *precaval sinus* or *ductus Cuvieri* (*pr. cv. v*) which is continued into the lateral extremity of the sinus venosus.

There are two *portal* systems of veins, the *renal portal* and the *hepatic portal* (*h. p. v*), by which the kidneys and liver, respectively, are supplied with venous blood. The *caudal vein* (*cd. v*), which brings back the blood from the tail, running, along with the caudal artery, through the inferior arches of the vertebræ, divides on entering the abdominal cavity into right and left *renal portal* veins (*r. p. v*), which end in a number of afferent renal veins supplying the kidneys.

The *hepatic portal* vein (*h. p. v*) is formed by the confluence of veins derived from the intestine, stomach, pancreas, and spleen, and runs forwards to enter the liver a little to the right of the middle line. The blood from the liver enters the sinus venosus by two *hepatic sinuses* (*h. v*) placed close together.

The fore-brain consists of a rounded, smooth prosencephalon (Fig. 219, V. H), divided into two lateral parts by a very shallow median longitudinal groove. From its anterolateral region each half gives off a thick cord, which dilates into a large mass of nerve matter, the *olfactory lobe* (*L. ol*), closely applied to the posterior surface of the corresponding olfactory capsule. The diencephalon (*ZH*) is comparatively small; its roof is very thin, while the floor is composed of two thickish masses, the *optic thalami*. Attached to the roof is a slender tube, the *epiphysis cerebri* or *pineal body* (*Gp*), which runs forwards and terminates in a slightly dilated extremity fixed to the membranous part of the roof of the skull. Projecting downwards from its floor are two rounded bodies, the *lobi inferiores*, which are dilated portions of the *infundibulum;* and attached to this, behind, is a thin-walled sac,—the *pituitary body* or *hypophysis cerebri* having a pair of thin-walled vascular lateral diverticula, — the *sacci vasculosi*, and having on its ventral surface a median tubular body attached at its posterior end to the floor of the skull. In front of the infundibulum, and also on the lower surface of the diencephalon, is the *optic chiasma*, formed by the decussation of the fibres of the two optic nerves. The mid-brain (*MH*) consists of a pair of oval *optic lobes* dorsally, and ventrally of a band of longitudinal nerve-fibres corresponding to the *crura cerebri* of the higher vertebrate brain. The cerebellum (*HH*) is elongated in the anteroposterior direction, its anterior portion overlapping the optic lobes, and its posterior the medulla oblongata. Its surface is marked with a few fine grooves. The medulla oblongata (*NH*), broad in front, narrows posteriorly to pass into the spinal cord. The *fourth ventricle* (*F. rho*) is a shallow space on the dorsal aspect of the medulla oblongata covered only by a thin vascular membrane, the *choroid plexus;* it is wide in front and gradually narrows posteriorly. At the sides of the anterior part of the fourth ventricle are a pair of folded ear-shaped lobes, the *corpora restiformia.*

The fourth ventricle is continuous behind with the central canal of the spinal cord. In front it is continuous with a narrow passage, the *iter* (*iter*), which opens anteriorly into a wider space, the *diacœle* or *third ventricle* (*dia*) occupying the interior of the diencephalon. From this opens in front a median *prosocœle*, which gives off a pair of *paracœles* (*para*) extending into two lateral portions of the prosencephalon.

A series of nerves arise in pairs from the brain and spinal cord. From the spinal cord the nerves arise segmentally, one pair corresponding to each myomere, and pass through apertures in the neural arches of the vertebræ. Each arises by two roots, a dorsal and a ventral. The dorsal root is dilated into a ganglion, and contains only sensory fibres; the ventral root is non-ganglionated, and is motor. A longitudinal ganglionated *sympathetic nerve*, extending along the dorsal region of the cœlome, is connected with the spinal nerves, and sends branches to the viscera, blood-vessels, etc.

From the brain arise ten pairs of nerves, some of which are sensory, others motor, others mixed. Three are the nerves of the principal sense organs: the first, or *olfactory*, supplying the organ of smell (Fig. 228, *olf. s*); the second, or *optic*, the retina of the eye, and the eighth, or *auditory*, the organ of hearing. The third, or *oculomotor*, the fourth, or *trochlear* (*path*), and the sixth, or *abducent*, go to the muscles of the eye; the fifth, or *trigeminal* (*oph. V*, *mx. V*, *mnd. V*), to the snout and jaws; the seventh, or *facial* (*oph. VII*, *pl. VII*, *hy. mnd. VII*), to the palate, lower jaw, and hyoid arch; the ninth, or *glossopharyngeal* (*gl. ph*), to the

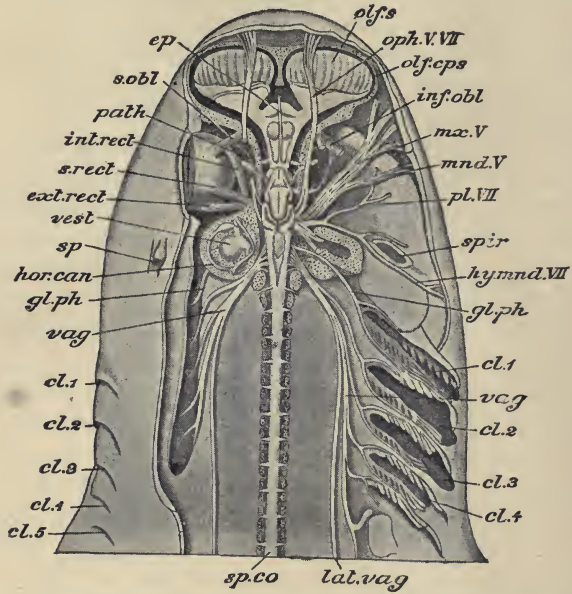
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FIG. 228.—**Scyllium catulus.** Dissection of the brain and spinal nerves from the dorsal surface. The right eye has been removed. The cut surfaces of the cartilaginous skull and spinal column are dotted. The ophthalmicus profundus and the buccal branch of the facial are not represented. *cl. 1–cl. 5*, branchial clefts; *ep*, epiphysis; *ext. rect*, external rectus muscle of the eye-ball; *gl. ph*, glossopharyngeal; *hor. can*, horizontal semicircular canal; *hy. mnd. VII*, hyomandibular portion of the facial; *inf. obl*, inferior oblique muscle; *int. rect*, internal rectus muscle; *lat. vag*, lateral branch of vagus; *mx. V*, maxillary division of the trigeminal; *olf. cps*, olfactory capsule; *olf. s*, olfactory sac; *oph. V. VII*, superficial ophthalmic branches of trigeminal and facial; *path*, fourth nerve; *pl. VII*, palatine branch of facial; *sp. co*, spinal cord; *spir*, spiracle; *s. rect*, superior rectus muscle; *s. obl*, superior oblique; *vag*, vagus; *vest*, vestibule. (From Marshall and Hurst.)

hyoid and first branchial arches; and the tenth, or *vagus* (*vag*), to the remaining branchial arches, as well as to the heart, stomach, and lateral line.

Besides the lateral line, which is probably the seat of a delicate tactile sense, and the tongue, which is presumably an organ of taste, there are the three pairs of characteristic sensory organs, the structure and position of which are very characteristic of vertebrates. These are the olfactory organs, the eyes, and the auditory organs. The *olfactory organs* are a pair of cup-like sacs on the under side of the snout, enclosed in the olfactory capsules and opening externally by the nostrils. They are lined with mucous membrane, which is raised up into ridges so as to increase the surface. The general structure of the *eyes* has already been described (p. 356). The ear consists of the *membranous labyrinth* (p. 357), which is enclosed in the cartilage of the auditory region of the skull. It consists of a sac called the *vestibule* (Fig. 228, *vest*), with which are connected three tubes, called from their form the *semicircular canals*. Two of these, the anterior and posterior canals, are vertical in position, and are united with one another at their adjacent ends; at the other end each is dilated to form a bulb-like swelling, the *ampulla*. The third, or horizontal canal (*hor. can*), opens at each end into the vestibule, and has an ampulla at its anterior end. The vestibule gives off a tube, the *endolymphatic duct*, which opens at the auditory aperture already referred to on the top of the head. Endolymph containing otoliths (p. 358) fills the interior of the labyrinth, and it is immediately surrounded externally by a space containing a similar watery fluid, the *perilymph*. The fibres of the auditory nerve are distributed to various parts of the internal epithelium of the vestibule and semicircular canals. There seems little doubt that the membranous labyrinth has not only an auditory, but also an equilibrating function, *i.e.*, that the fish is enabled by its means to maintain its equilibrium in the water.

The kidneys (Fig. 227, *k*) are long flat lobulated bodies lying one on each side of the backbone in the posterior part of the abdominal cavity. From the ventral surface of each spring numerous delicate ducts which unite into a single tube, the *ureter*, opening directly into the cloaca in the female, in the male into a small paired chamber, the *urogenital sinus* (*ug. s*), which opens into the cloaca (*cl*).

In the male dogfish the testes are a pair of large soft organs situated in the body-cavity, and united with one another posteriorly. From the anterior end of each arise numerous delicate *efferent ducts*, which enter a long convoluted *spermiduct* or *vas deferens* (*v. def*) leading posteriorly to the urogenital sinus. In the female there is a single *ovary* suspended to the dorsal body-wall by a fold of peritoneum. In the adult it is studded all over with rounded projections, the *ova*. There are two oviducts, a right and a left, which extend along the whole length of the dorsal wall of the cœlom below the kidneys. Anteriorly they unite with one another below the gullet, and just in front of the line and at the point of junction is a single aperture of considerable size, by which both tubes communicate with the cœlom; posteriorly they open into the cloaca. About the anterior third of each oviduct is narrow; its posterior two-thirds is wide and distensible, and at the junction of the parts is a yellowish glandular mass, the *shell-gland*.

Internal impregnation takes place, the spermatic fluid of the male being passed, by means of the claspers, into the oviducts of the female. The ova, when ripe, break loose from the surface of the ovary into the cœlom, and thence pass, through the common aperture, into one or other of the oviducts, where fertilisation (p. 393) occurs. As it passes into the dilated portion of the oviduct, the oosperm (p. 60) of Scyllium becomes surrounded by a horn-like egg-shell (Fig. 229), secreted by the shell-gland, and having the form of a pillow-case produced at each of its four corners into a long tendril-like process. The eggs are laid among seaweed, to which they become attached by their tendrils. In some other dogfishes (*Acanthias*, *Mustelus*) a mere vestige of the egg-shell is formed, and the eggs undergo the whole of their development in the oviducts, the young being eventually born alive with the form and proportions of the adult.

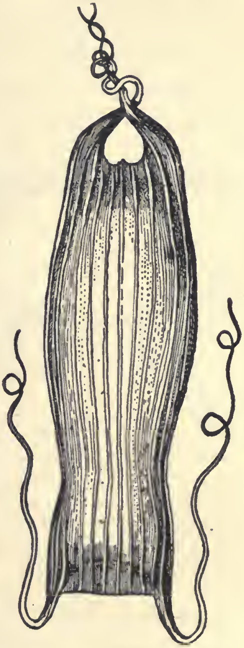

FIG. 229. — **Dogfish, egg-case.** (After Dean.)

The great size of the egg is due to the immense quantity of yolk which it contains; its protoplasm is almost entirely aggregated at one pole in the form of a small disc. When segmentation of the oosperm takes place, it affects the protoplasm alone, the inactive yolk taking no part in the process. The disc of protoplasm divides to form a little heap of cells, the *blastoderm*, situated at one pole of the undivided sphere of yolk. The blastoderm subsequently spreads out as a sheet of cells over the yolk which it ultimately completely encloses. While this extension of the blastoderm is taking place, its middle part becomes raised up into a ridge-like thickening, which is moulded, step by step, into the form of the embryo fish. The head, trunk, and tail acquire distinctness, and become more and more clearly separated off from the bulk of the egg, the latter taking the form of a *yolk-sac* attached by a narrow stalk to the ventral surface of the embryo (Fig. 230).

In this condition the various parts of the adult fish can be recognised, but the proportions are different, and the head presents several peculiarities. The gill-filaments (*br. f*) are so long as to project through the external branchial apertures and the spiracle (*br. f*) in the form of long threads abundantly supplied with blood-vessels, and apparently serving for the absorption of nutriment — the albumen in the egg-shell in the case of Scyllium, secretions of the oviduct in the viviparous forms. Besides this mode of nutrition the yolk-sac communicates with the intestine by a narrow duct, through which absorption of its contents is constantly

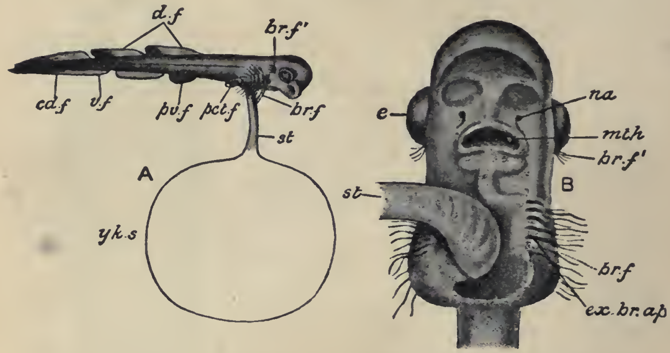

FIG. 230. — A, embryo of **Scyllium** with yolk-sac (× 1½); B, under-side of head enlarged. *br. f*, branchial filaments protruding through gill-clefts; *br. f'*, branchial filaments projecting through spiracle; *cd. f*, caudal fin; *d. f*, dorsal fins; *e*, eye; *ex. br. ap.* external branchial apertures; *mth*, mouth; *na*, nostrils; *pct. f*, pectoral fin: *pv. f*, pelvic fin; *st*, yolk-stalk; *v. f*, ventral fin; *yk. s*, yolk-sac. (After Balfour, slightly altered.)

going on. By the time the young fish is ready to be born or hatched, the greater part of the yolk-sac has been drawn into the cœlom, a mere vestige of it still dangling from the ventral surface of the body.

In all the most important features of their organisation there is a considerable degree of uniformity among the Elasmobranchii.

In general shape the sharks (Fig. 231), for the most part, are somewhat fusiform and slightly compressed laterally. In the rays (Fig. 232), on the other hand, there is great dorso-ventral compression. The head is in many cases produced forwards into a long rostrum, which is of immense length and bordered with triangular teeth in the saw-fish shark (*Pristiophorus*) and saw-fish ray (*Pristis*). In the hammer-head shark the anterior part of the head is elongated transversely.

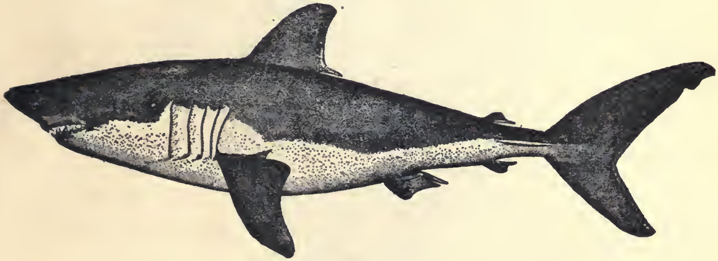

FIG. 231. — Shark (Lamna cornubica). (From Dean's *Fishes*.)

There are well-developed median and paired fins. The caudal fin is well developed, and, as a rule, strongly heterocercal in the sharks and shark-like rays, feebly developed in most of the latter group. The dorsal and ventral fins are large in the sharks, the former completely divided into two; in the rays the dorsal fin is usually small, and the ventral absent. The paired fins are very differently developed in the two groups. In the sharks both pairs are well developed, the pectoral being the larger. In the rays or skates the pectoral fins are extremely large, very much larger than the pelvic, fringing the greater part of the length of the flattened body, and becoming prolonged forwards on either side and even in front of the head, so that the animal presents the appearance of a broad fleshy leaf.

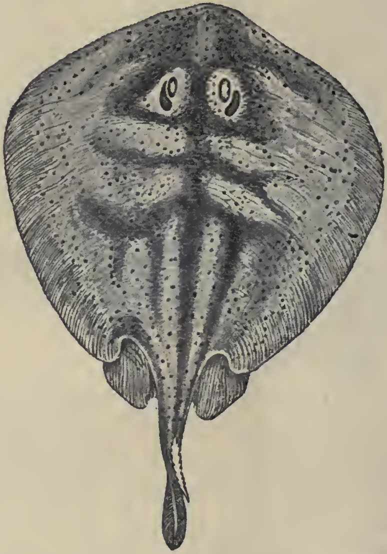

Fig. 232. — European sting-ray (**Urolophus cruciatus**). (After Günther.)

In all recent Elasmobranchs the male has, connected with the pelvic fins, a pair of grooved appendages, the *claspers* or *pterygodia*, which subserve copulation.

The mouth is situated on the ventral surface of the head, usually a considerable distance from the anterior extremity.

In front of each angle of the mouth on the ventral surface is the opening of one of the olfactory sacs, each of which is connected by a groove, the naso-buccal groove, with the mouth-cavity. Behind the mouth, on the dorsal surface in the rays, and at the side in the sharks, is the spiracle. Along the sides of the neck in the sharks, and on the ventral surface in the rays, is on either side a row of slit-like apertures, the branchial slits or branchial clefts. These are usually five in number on each side; but in *Hexanchus* and *Chlamydoselachus* there are six, and in *Heptanchus* seven. A large cloacal opening is situated just in front of the root of the tail, and a pair of small openings placed in front of it, the *abdominal pores*, lead into the abdominal cavity.

When the integument develops any hard parts, as is the case in the majority of the Elasmobranchs, they take the form, not of regular scales, as in most other fishes, but of numerous hard bodies, which vary greatly in shape, are usually extremely minute, but are in some cases developed, in certain parts of the surface, into prominent tubercles or spines. When these hard bodies are, as is commonly the case, small and set closely together in the skin, they give the surface very much the character of a fine file; and the skin so beset, known as "shagreen," is used for various polishing purposes in the arts. This is the *placoid* form of exoskeleton, to which reference has been already made. Each of the hard bodies has the same structure as a tooth, being composed of dentine, capped with enamel, and supported on a bony base, representing the cement or *crusta petrosa* of the tooth. The dermal fin-rays are horny. The skeleton is composed of cartilage, with, in many cases, deposition of bony matter in special places, notably in the jaws and the vertebral column. The entire spinal column may be nearly completely cartilaginous (*Hexanchus* and *Heptanchus*), but usually the centra are strengthened by

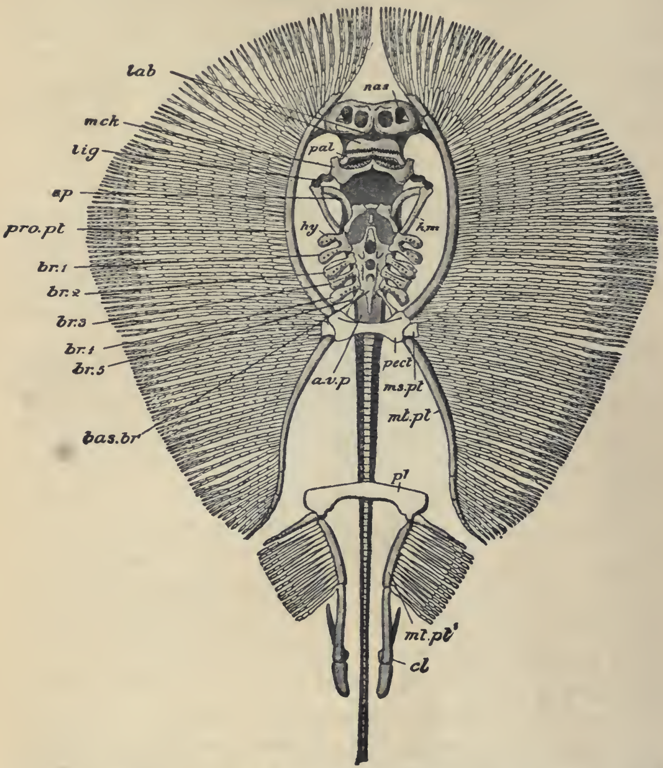

FIG. 233. — Skeleton of sting-ray (**Urolophus testaceus**), ventral view. *a. v. p*, anterior vertebral plate; *bas. br*, basi-branchial plate; *br. 1–br. 5*, branchial arches. The branchial rays are represented as having been removed, the round dots indicate their articulations with the arches *cl*, skeleton of clasper; *h. m*, hyomandibular; *hy*, hyoid arch; *lab*, labial cartilage; *lig*, ligament connecting the hyomandibular with the palato-quadrate and Meckel's cartilage; *mck*, Meckel's cartilage; *ms. pt*, mesopterygium; *mt. pt*, metapterygium of pectoral fin; *ml. pt'*, metapterygium of pelvic fin; *nas*, nasal cartilage; *pal*, palato-quadrate; *pect*, pectoral arch; *pl*, pelvic arch; *pro. pt*, propterygium; *sp*, spiracular cartilage.

radiating or concentric lamellæ of calcified cartilage or bone, or they may be completely calcified. They are deeply amphicœlous, the remains of the notochord persisting in the large spaces between the concave surfaces of contiguous centra. In the rays the anterior part of the spinal column becomes converted into a continuous solid cartilaginous and bony mass — the *anterior vertebral plate* (Fig. 233, *a. v. p*). Two main regions only are distinguishable in the spinal column — the pre-caudal region and the caudal, the latter being distinguished by the presence of inferior or hæmal arches. In the pre-caudal region short ribs may be developed, but these are sometimes rudimentary or entirely absent.

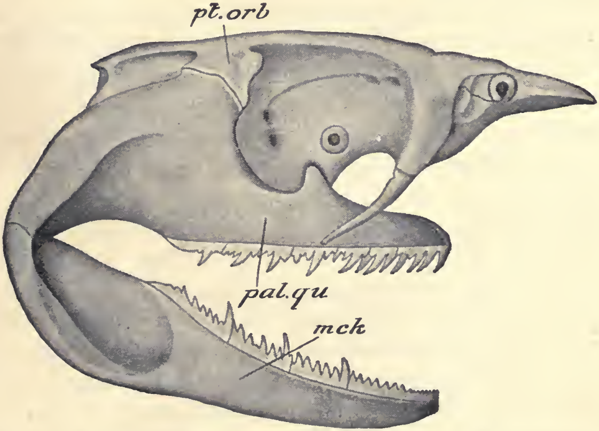

FIG. 234. — Lateral view of the skull of **Heptanchus**. *mck*, Meckel's cartilage; *pal. qu*, palato-quadrate; *pt. orb*, post-orbital process of the cranium, with which the palato-quadrate articulates. (After Gegenbaur.)

The skull is an undivided mass of cartilage, hardened, in many cases, by deposition of osseous matter, but not containing any separate bony elements. In all, the jaws are connected with the skull through the intermediation of a hyomandibular cartilage, or proximal element of the hyoid arch; in the great majority this is the sole articulation of the jaws with the skull posteriorly, and the skull is on that account said to be *hyostylic;* but in Hexanchus and Heptanchus (Fig. 234) the upper jaw has a direct articulation with the skull behind the orbit, and the arrangement is termed *amphistylic.* There are always five pairs of branchial arches, except in Hexanchus and Chlamydoselachus, which have six, and Heptanchus, in which there are seven.

The basal cartilages of the pectoral fin are typically three, as in the dogfish, but there are sometimes four, and the number may be reduced to two. There are usually two such cartilages in the pelvic fin, and one alone may be present.

Electric organs — organs in which electricity is formed and stored up, to be discharged at the will of the fish — occur in several Elasmobranchs. They are best developed in the electric rays (*Torpedo* and *Hypnos*) in which they form a pair of large masses running through the entire thickness of the body between the head and the margin of the pectoral fin. By means of the electric shocks which they are able to administer at will to animals in their immediate neighbourhood, these torpedo rays are able to ward off the attacks of enemies and to kill or paralyse their prey.[1]

Teeth are developed in all on the palato-quadrate or upper jaw and Meckel's cartilage or the lower jaw. They are arranged in several parallel rows, and are developed from a groove at the back of the jaw, successive rows coming to the front, and, as they become worn out, falling off and becoming replaced by others. In the sharks the teeth are usually large and may be long, narrow, and pointed, or triangular with serrated edges, or made up of several sharp cusps; in the rays, however, the teeth are more or less obtuse, sometimes, as in the eagle rays, forming a continuous pavement of smooth plates covered with enamel, adapted to crushing food consisting of such objects as shell-fish and the like.

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[1] *Torpedo occidentalis* occurs on the southern coast of New England.

The various divisions of the *enteric canal* are similar in all members of the class to what has already been described in the case of the dogfish. A spiral valve is always present in the large intestine, though its arrangement varies considerably in the different families. The rectum always terminates in a *cloaca* into which the urinary and genital ducts also lead.

The respiratory organs have in all the same general arrangement as in the dogfish. The inter-branchial septa are of considerable breadth and the gill-filaments are attached to them along their entire length.

The heart also has in all essential respects the same structure throughout the group, the most characteristic feature being the presence of a conus arteriosus which is rhythmically contractile and contains several rows of valves.

Impregnation is internal in all the Elasmobranchii with the exception of the Greenland shark (*Læmargus*), the claspers acting as intromittent organs by whose agency the semen is transmitted into the interior of the oviducts. In all Elasmobranchs the ova are very large, consisting of a large mass of yolk with, on one side, a disc of protoplasm, the *germinal disc*. The ripe ovum ruptures the delicate wall of the follicle in which it is enclosed and escapes into the abdominal cavity to enter one of the oviducts, as already stated in the case of the dogfish. Impregnation takes place in the oviduct, and in the oviparous forms the impregnated ovum becomes enclosed in a chitinous shell secreted by the shell-gland. Enclosed in the shell, the form of which varies in different groups, the egg passes to the exterior and undergoes development until the young fish is fully formed, when it escapes by rupturing the egg-shell. In the viviparous forms, on the other hand, the ovum undergoes its development in the uterus; and the young fish, when it escapes to the exterior, has assumed all the features of the adult.

The habits of the active, fierce, and voracious sharks, which live in the surface waters of the sea waging war on all and sundry, are in strong contrast with those of the more sluggish rays, which live habitually on the bottom, usually in shallow water, and feed chiefly on crustaceans and molluscs, with the addition of such small fishes as they can capture.

As a group, the Elasmobranchs, more particularly the sharks, are distinguished by their muscular strength, the activity of their movements, and also by the acuteness of their senses of sight and smell. The only deep-water Elasmobranch known is a species of ray, which extends to a depth of over 600 fathoms.

Sub-class III. Teleostomi[1]

The great majority of existing fishes belong to the subclass Teleostomi. As a matter of convenience we may look upon the Teleostomi as consisting of two main divisions,—the Teleostei, in which are included all the commonest and most familiar fishes, such as the perch, pike, mackerel, cod, sole, herring, eel, salmon, etc., and the Ganoidei or Ganoids, such as the sturgeon, body pike (*Lepidosteus*), and bow-fin (*Amia*) of North America, and the *Polypterus* of the Nile. They are distinguished from Elasmobranchs by the possession of an operculum or gill-cover, by the absence of a cloaca, by having the primary skull and shoulder-girdle complicated by the addition of membrane-bones, and by possessing bony instead of horn-like fin-rays.

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[1] Sub-class II, the small group Holocephali, or Chimæras and their allies, is one of the groups omitted from this work. See Preface.

A typical Teleostomian, such as a trout (Fig. 235)[1] or a herring, has a long compressed body nearly half of which is formed by the tail, pointed anterior and posterior ends, a large vertical tail-fin, a head of moderate size, and a terminal mouth. Such a form is eminently fitted for progression through the water. But from this characteristic fish form there are many striking deviations. The body may be greatly elongated and almost cylindrical, as in the eels; or of great length and strongly flattened from side to side, as in the ribbon-fishes; or the head may be of immense proportional size and strongly depressed, as in certain shore-fishes, such as the fishing-frog; or, as in the beautiful reef-fishes, the whole body may be as high as it is long. The mouth sometimes has a ventral position, as in the Elasmobranchs, with the snout prolonged over it; this is the case,

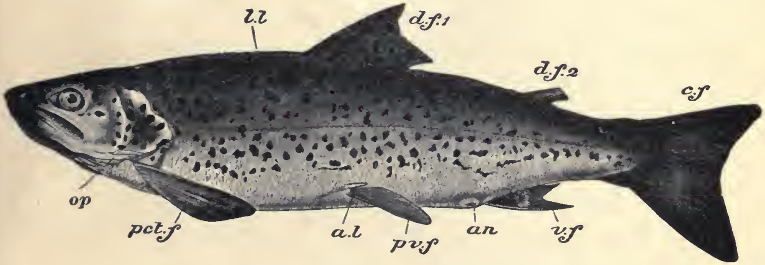

FIG. 235. — **Salmo fario.** *a. l*, adipose lobe of pelvic fin; *an*, anus; *c. f*, caudal fin; *d. f. 1*, first dorsal; *d. f. 2*, second dorsal or adipose fin; *l. l*, lateral line; *op*, operculum; *pct. f*, pectoral fin; *pv. f*, pelvic fin; *v. f*, ventral fin. (After Jardine.)

[1] Our common brook trout in the northeastern states is *Salmo fontinalis*.

for example, in the sturgeons (Fig. 240). On the other hand, in the ground-feeding "star-gazers" and some others, the lower jaw is underhung like that of a bull-dog, and the mouth becomes dorsal in position. A *beak* may be produced by the elongation of the upper jaw, as in the sword-fish, or of the lower jaw, as in the half-beak or czar-fish, or of both jaws as in the bony pike.

An *operculum* or gill-cover (*op*), a flap which covers the gills of each side and bounds in front the single, usually crescentic gill-opening, is always present, and is supported by four membrane bones. Ventrally the operculum is produced into a thin membranous extension, the *branchiostegal membrane*, which is in nearly all cases supported by a series of bony rays. Spiracles are absent except in certain of the Ganoids.

There are dorsal, ventral, and caudal median fins. The dorsal is usually divided into two; in a few it is partly or wholly supported by a series of finlets. The caudal is in the majority of a type to which the term *homocercal* is applied. The homocercal caudal fin is divided into two equal or sub-equal lobes, upper and lower, so that it appears symmetrical externally, though the posterior portion of the spinal column which supports it is strongly bent upwards and terminates in the upper lobe. In some of the Ganoids, however, this upward curvation of the caudal part of the spinal column does not occur, and the tail is symmetrical internally as well as externally; in these the tail is said to be *diphycercal*. In many Ganoids the tail is *heterocercal*, as in nearly all the Elasmobranchs (p. 367). In some Teleostomi dorsal, caudal, and ventral fins are united into a continuous fold. The dermal fin-rays of the caudal fin and a portion or all of those of the rest of the fins are slender flexible rods divided into a series of short segments and usually branching at the free ends. In many, however, the anterior portions of the dorsal, ventral, and pelvic fins are supported not by flexible jointed rays, but by stiff unjointed sharp *spines*.

The paired fins, pectoral and pelvic, are usually thin and flexible, supported mainly, or exclusively, by jointed rays. The pectorals always retain their normal position, just behind the gill-cleft, but the pelvics always become more or less shifted forwards from their typical position beside the vent; when they are not placed as far forwards as the middle of the abdomen, they are said to be abdominal in position; when further forwards, nearly beneath the pectorals, they are said to be thoracic; when still further, actually in front of the pectorals and beneath the throat, they are said to be *jugular* in position.

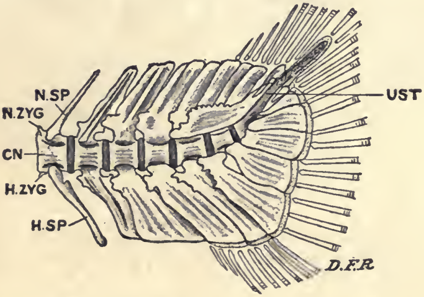

FIG. 236. — **Salmo fario.** Caudal end of vetebral column. **CN**, centrum; *D. F. R*, dermal fin-rays; **H. SP**, hæmal spine; **H. ZYG**, hæmal zygapophysis; **N. SP**, neural spine; **N. ZYG**, neural zygapophysis; **UST**, urostyle.

A very remarkable deviation from the typical form occurs in the flat-fishes (*Pleuronectidæ*, including the soles, plaice, flounders, turbots, etc.). The body (Fig. 237) is very deep and strongly compressed; the fish habitually rests on the bottom, in some species on the right, in others on the left side. The under side is usually pure white, the upper dark. The eyes are both on the upper side, and the skull is distorted so as to adapt the orbits to this change of position.[1]

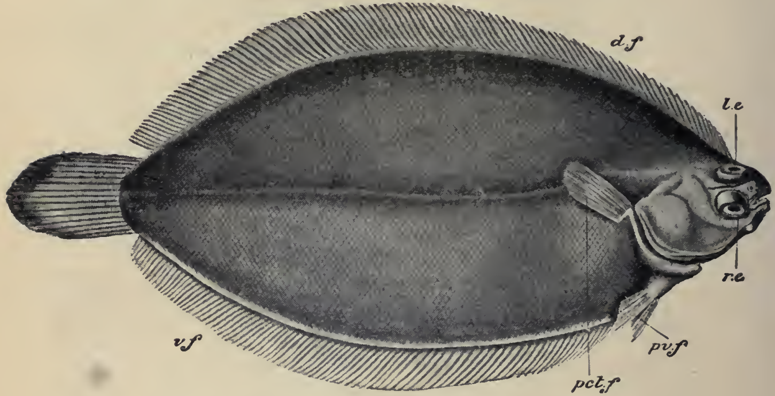

Fig. 237. — **Pleuronectes cynoglossus** (craig-fluke), from the right side. *d. f*, dorsal fin; *l e*, left eye; *pct f*, pectoral fin; *pv. f*, pelvic fin; *r. e*, right eye; *v. f*, ventral fin. (After Cuvier.)

In many Teleostei, such as the eels, the skin is devoid of hard parts; but in most cases there is an exoskeleton developed in the derm. In the majority this takes the form of scales, rounded plates of bone embedded in pouches of the derm, and overlapping one another from behind forwards. When the free border of the scales presents an even curve, they are called *cycloid* scales; when the free edge is produced into small spines, they are distinguished as *ctenoid* scales (Fig. 238). In exceptional cases the scales may be so large and strong as to form a rigid armour.

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[1] Our common flounders are *Paralichthys dentatus* from the southern coast of New England, and *Pseudopleuronectes americanus* from the coast north of Cape Cod.

Sometimes there is an armour formed of stout bony plates, or *scutes*, while in other cases, as in the "file-fishes," the exoskeleton takes the form of minute spines like the shagreen of sharks, or as in many globe-fishes of long bony spines; lastly, in Polypterus (Fig. 239) and Lepidosteus are found *rhomboid* or *ganoid* scales in the form of rhomboidal plates of bone covered externally by a layer of enamel or ganoin and joined together by pegs and sockets.

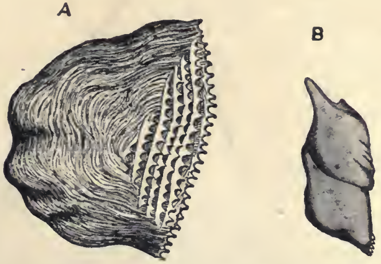

FIG. 238. — A, ctenoid scale; B, ganoid scale. (After Günther.)

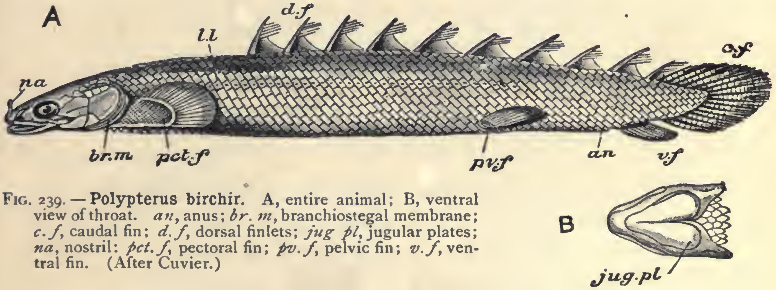

FIG. 239. — **Polypterus birchir.** A, entire animal; B, ventral view of throat. *an*, anus; *br. m*, branchiostegal membrane; *c. f*, caudal fin; *d. f*, dorsal finlets; *jug pl*, jugular plates; *na*, nostril: *pct. f*, pectoral fin; *pv. f*, pelvic fin; *v. f*, ventral fin. (After Cuvier.)

In the sturgeon the spinal column consists of a persistent notochord with cartilaginous arches; in the rest bony vertebræ are present, the centres of which are nearly always bi-concave.

In the sturgeons (Fig. 240) and their allies the cranium is an undivided mass of cartilage with a few isolated cartilage bones, and covered over dorsally by membrane bones. In most of the other members of the group it is mainly or entirely composed of numerous cartilage and membrane bones (Fig. 240). Both upper and lower jaws are bounded by membrane bones (*p. mx*, *mx*, *dent*). The jaws are connected with the skull by the intermediation of a hyomandibular (*hyom*) which, however, probably does not correspond with the cartilage so named in the dogfish and other Elasmobranchs. The pectoral arch is complicated by the addition of membrane bones, of which the most constant are a pair of large *clavicles*. The pelvic arch is vestigial or absent.

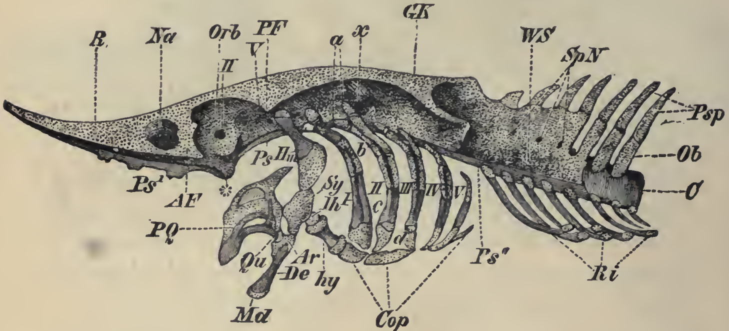

FIG. 240.—Skull of sturgeon, with the membrane bones removed. *a*, pharyngobranchial; *AF*, antorbital process; *AR*, articular; *b*, epibranchial; *c*, ceratobranchial; *C*, notochord; *Cop*, basi-branchials; *d*, hypobranchial; *De*, dentary; *GK*, auditory capsule; *HM*, hyomandibular; *hy*, hyoid cornu; *Ih*, inter-hyal; *Md*, mandible; *Na*, nasal capsule; *Gb*, neural arches; *PF*, post-orbital process; *PQ*, palato-quadrate; *Ps*. *Ps'*. *Ps''*, parasphenoid; *Psp*, neural spines; *Qu*, quadrate; *R*. rostrum; *Ri*, ribs; *Sp. N*, foramina for spinal nerves; *Sy*, symplectic; *WS*, vertebral column; *n*, vagus foramen; *I–V*, branchial arches. (From Wiedersheim's *Comparative Anatomy*.)

Two genera of Teleostomi possess electric organs, — the electric catfish (*Malapterurus*) and the electric eel (*Gymnotus*) ; the former occurs in fresh waters of tropical Africa, and the latter in Brazil and the Guyanas. Some Teleostomi are toothless, but in most instances teeth are present, and may be developed, not only on the pre-maxilla and maxilla of the upper jaw, and the dentary of the lower, but on a

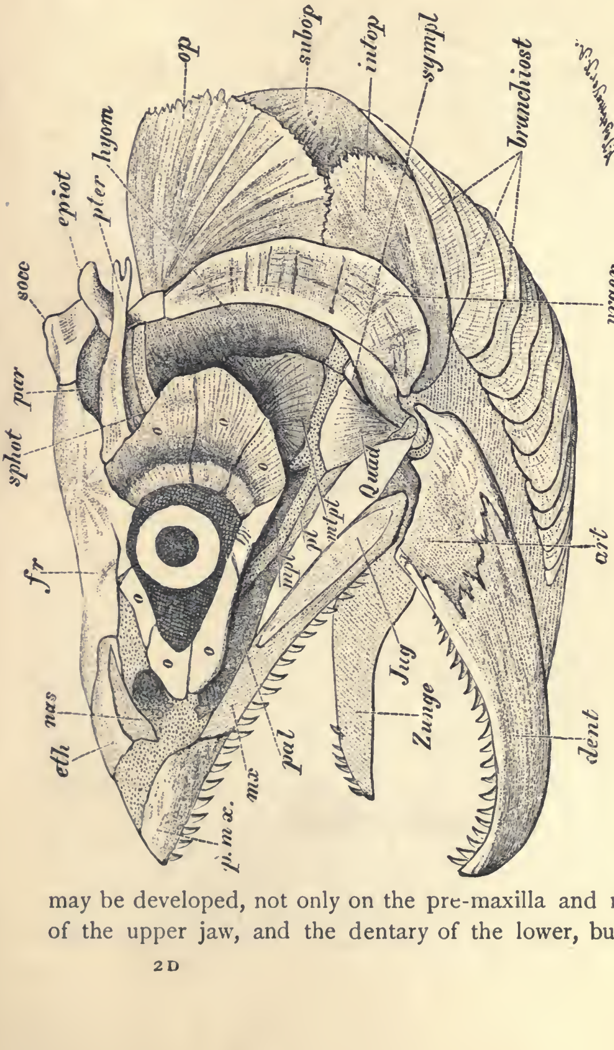
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FIG. 241.—**Salmo fario**, the entire skull, from the left side. *art*, articular; *branchiost*, branchiostegal rays; *dent*, dentary; *epiot*, epiotic; *eth*, supra-ethmoid; *fr*, frontal; *hyom*, hyomandibular; *intop*, inter-opercular; *Jug*, jugal; *mpt*, mesopterygoid; *mtpt*, metapterygoid; *mx*, maxilla; *nas*, nasal; *o*, sub-orbitals; *op*, opercular; *pal*, palatine; *par*, parietal; *pmx*, pre-maxilla; *praop*, pre-opercular; *pt*, pterygoid; *pter*, pterotic; *Quad*, quadrate; *socc*, supra-occipital; *sphot*, sphenotic; *subop*, sub-opercular; *sympl*, symplectic; *Zunge*, basi-hyal. (From Weidersheim's *Vertebrata*.)

number of other bones in the wall of the mouth. In most of the Teleostei the maxilla is devoid of teeth, and does not enter into the upper boundary of the mouth opening. In the great majority the teeth are small and very numerous, adapted for preventing the struggling prey from slipping out of the mouth, but quite unfitted for either tearing or crushing; but in many instances teeth are comparatively large and few in number, and in some (Fig. 242) there is a marked differentiation of the teeth, those in front of the jaws being pointed or chisel-shaped, and adapted for seizing or cutting, while the back teeth have rounded surfaces adapted for crushing. The teeth may be either simply embedded in the mucous membrane so as to be detached when the bones are macerated or boiled, or they may be implanted in the sockets of the bone or ankylosed to it. Their succession is perpetual, *i.e.*, injured or worn-out teeth are replaced at all ages. The Ganoids have a spiral valve in the intestine; this is absent in the Teleostei. Cœca (the *pyloric cœca*) are commonly developed at the junction of the stomach and small intestine. The anus is always distinct from, and in front of, the urogenital apparatus, there being no cloaca such as occurs in Elasmobranchs. The gills are usually

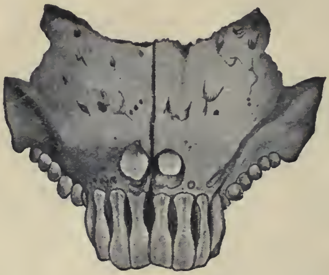

FIG. 242.—Premaxillæ of **Sargus**, showing teeth. (After Owen.)

comb-like, consisting of rows of slender branchial filaments. The inter-branchial septa are reduced as compared with those of the Elasmobranchs, the branchial filaments projecting freely beyond them. As a rule, the gills are developed in the first four branchial arches.

A characteristic structure of the Teleostomi is the *air-bladder* or *swimming bladder*, which, however, is not present in all. It is an elongated sac with elastic walls situated in the body-cavity immediately below the spinal column. In some cases (Ganoids and some Teleostei) it communicates with the gullet by a duct, the *pneumatic duct;* in the rest it is a closed sac. It is sometimes divided into compartments, or produced into lateral offshoots. In some of the Ganoids its wall is sacculated, assuming an appearance not unlike that of the lung of one of the higher air-breathing vertebrates. The air-bladder seems able to act as a sort of accessory organ of respiration. Its normal function, however, appears to be hydrostatic, *i.e.*, it serves to keep the fish of the same specific gravity as the water; variations in pressure, as the fish ascends or descends, are regulated by absorption or secretion of gas.

In the Ganoids the heart has a structure very similar to that of the dogfish, consisting of a sinus venosus, auricle, ventricle, and conus arteriosus — the last being rhythmically contractile like the other chambers, and containing rows of valves. In Teleostei there is no such conus arteriosus; but there is always a large bulb-like dilation of the base of the ventral aorta, the *bulbus aortæ*. The optic nerves of the Ganoids agree with those of Elasmobranchs and of Vertebrates in general in forming a chiasma, whereas in the Teleostei they simply cross one another or decussate.

Most Teleostomi are oviparous, the eggs being impregnated after they are laid. Many instances of parental care of the young are known, the most familiar being that of the male stickleback, which constructs a nest of weeds fastened together by a glutinous secretion of the kidneys, and jealously guards the developing young. In the sea-horse (*Hippocampus*, Fig. 243) and the pipe fish (*Syngnathus*) the young are developed in a pouch in the abdomen of the male. In *Aspredo*, one of the cat-fish tribe, the eggs are pressed into the soft spongy skin of the belly, and thus carried about by the parent. The ova, although containing a large proportional amount of yolk, are always small as compared with those of Elasmobranchs, never exceeding 5 to 10 mm. in diameter, and being usually much smaller.

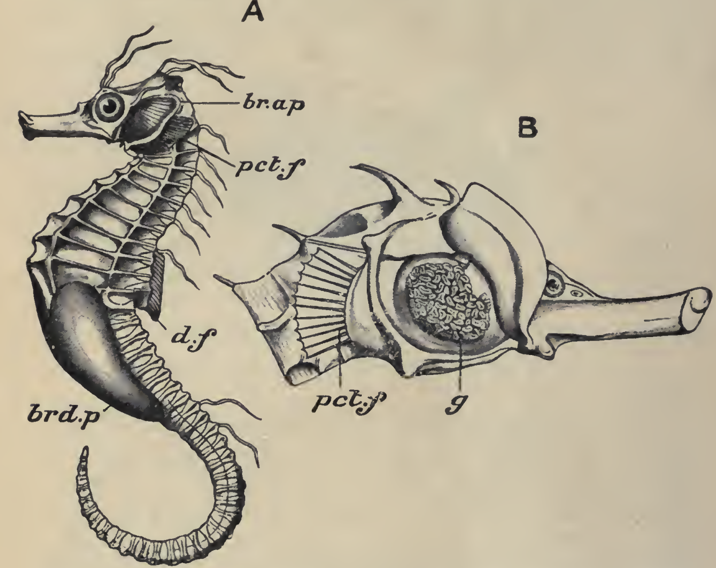

FIG. 243.—**Hippocampus** (sea-horse). In B, the operculum is removed to show the gills. *br. ap*, branchial aperture; *brd. p*, brood-pouch; *d. f*, dorsal fin; *g.* gills; *pct. f*, pectoral fin. (From Claus and Günther.)

They are rarely protected by an egg-shell. They are produced in immense numbers, a single female sometimes laying several millions. In such cases the mortality among the unprotected embryos and young is immense. The eggs may be *pelagic*, *i.e.*, so light as to float when laid, as in the cod, haddock, turbot, sole, etc., or *demersal, i.e.*, so heavy as to sink to the bottom, as in the herring, salmon, trout, etc.

Sub-class IV. Dipnoi

The Dipnoi or lung-fishes, comprising as their living representatives only the Queensland *Ceratodus* (Fig. 244), or Burnet salmon, and the mud-fishes, *Protopterus* and *Lepidosiren*, of certain South African and South American rivers respectively, are fishes of such well-marked and special features that by some zoologists they are separated from the true fishes and regarded as constituting a separate class of Vertebrates. One of their peculiar features is

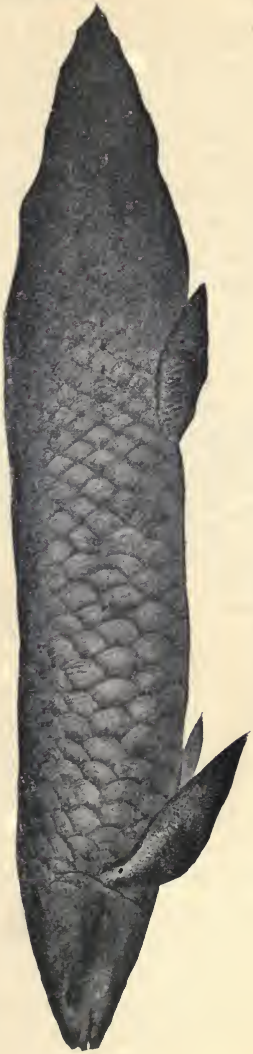

Fig. 244. — **Ceratodus Forsteri**. Reduced. (From Dean, after Günther.)

indicated by their name Dipnoi; not only do these animals breathe by means of gills like ordinary fishes, but they have a highly developed apparatus for the respiration of air — a single lung in the case of Ceratodus, a pair of lungs (united in front) in the other two genera. They have bony scales and dermal fin-rays; but the paired fins are constructed on a totally different type from those of any other living fish. The fin, pectoral or pelvic as the case may be, is leaf-like, or very long and narrow, and the skeleton (Fig. 245) consists of a central axis in the form of a slender, tapering, jointed rod of cartilage, with a row of smaller jointed rods of cartilage on either side of it. This form of fin-skeleton, which occurs in certain groups of fossil fishes, as well as in Dipnoi, has been termed the *archipterygium*. The notochord is persistent, and the cranium (Fig. 245) consists of a mass of cartilage with little ossification, but with the addition

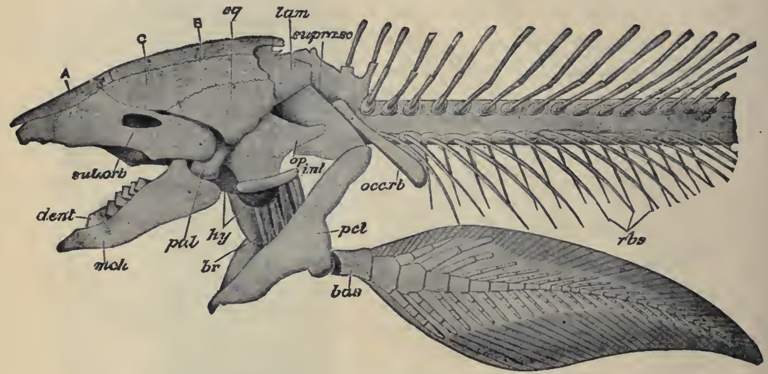

Fig. 245. — **Ceratodus Forsteri.** Lateral view of the anterior portion of the skeleton. A, anterior median membrane bone of the roof of the skull; B. posterior median membrane bone. *bas*, basal cartilage of the pectoral fin; *br*, branchial arches; *int*, inter-operculum; *lam*, plate overhanging branchial region; *mck*, Meckel's cartilage; *occ. rb*, occipital rib; *op*, operculum; *pal*, palato-quadrate; *pct*, pectoral arch; *rbs*, ribs; *sub. orb*, sub-orbital bones; *sq*, squamosal; *supra. sc*, supra-scapula.

of a number of membrane bones; the skull is *autostylic*, the lower jaw articulating with a palato-quadrate process (*pal*), corresponding to the palato-quadrate of the dogfish, but immovably fixed to the side of the skull. There are four or five cartilaginous branchial arches (*br*). The gills are covered over by an operculum. A cloaca is present, and the intestine contains a spiral valve. The structure of the heart is more complicated than in ordinary fishes, owing to the sinus venosus and the auricle being both imperfectly divided into two parts. There is a contractile conus arteriosus, which has a spirally twisted form, and is partly or completely divided internally by a longitudinal septum. A *pulmonary artery*, carrying blood to the lung or lungs, is given off from the afferent branchial system. The blood is returned from the lung or lungs by means of a *pulmonary vein*, which opens into the left division of the sinus venosus, and through it reaches the left division of the auricle.

CLASS III. AMPHIBIA

The larvæ of the newts or efts, and those of the frogs (familiar to every one under the name of tadpoles), bear a close resemblance in form and movements to the fishes. But, as they approach maturity, these fish-like larvæ undergo a metamorphosis, fitting them for the amphibious mode of life which gives its name to the class: pentadactyle limbs are developed, and lungs for breathing air take the place of gills as the organs of respiration, while a corresponding advance to a higher type of structure occurs in the other parts. The Amphibia thus occupy an intermediate position between the fishes on the one hand and the higher air-breathing Vertebrates (reptiles, birds, and mammals) on the other. In addition to the possession of limbs constructed on the pentadactyle type, or type of the *cheiropterygium*, the Amphibia differ from the fishes in the entire absence of fin-rays, and from all fishes but the Dipnoi, in the presence of lungs for breathing air in the adult: the larval gills become absorbed in the majority of Amphibia before maturity is reached, but in some are retained throughout life, the animal breathing, like the Dipnoi, by means of both lungs and of gills.

The most convenient example of the Amphibia for special study is a frog. The following description and figures have reference more specially to the European species of the genus *Rana*, — *R. temporaria* and *R. esculenta*, — but they will be found to apply to any American frog or toad, except in a few features which are chiefly quite superficial, some of which will be referred to subsequently.

The *trunk* is short and stout, and is continued, without the intermediation of a neck, into the broad depressed *head*. There is no trace of a tail, the anus being terminal. The *mouth* also is terminal, and is characterised by its extraordinary width, the gape extending considerably behind the eye. On the dorsal surface of the snout are the small *nostrils;* the *eyes* are large and prominent, and each is provided with an *upper eyelid* in the form of a thick fold of skin and a *nictitating membrane* — a much thinner fold which arises from the lower margin of the eye and can be drawn up over it. Close behind the eye is a circular area of tensely stretched skin, the *tympanic membrane*, a structure not met with in any fish; as we shall see, it is an accessory part of the auditory organ. There is no trace of branchial apertures.

The back has a peculiar bend or hump, in the sitting posture, marking the position of the sacral vertebra (see p. 410). The limbs are of very unequal size. The *fore-limbs* are short, and each consists of an *upper arm*, which, in the ordinary position, is directed backwards and downwards from the shoulder joint; a *fore-arm*, directed downwards and forwards from the elbow; and a *hand*, ending in four short tapering *digits*, directed forwards. The *hind-limb* is of great size; in the usual squatting posture the *thigh* is directed downwards, outwards, and forwards from the thigh-joint, the *shank* inwards, backwards, and upwards from the knee. The *foot* consists of two parts,—a *tarsal region* directed downwards from the heel-joint, and five long, slender *digits* united by thin folds of skin or *webs*. Thus the limbs are placed in such a way that the elbow and knee face one another, and the first digit — that of the hand probably representing the second or *index-finger*, that of the foot, the

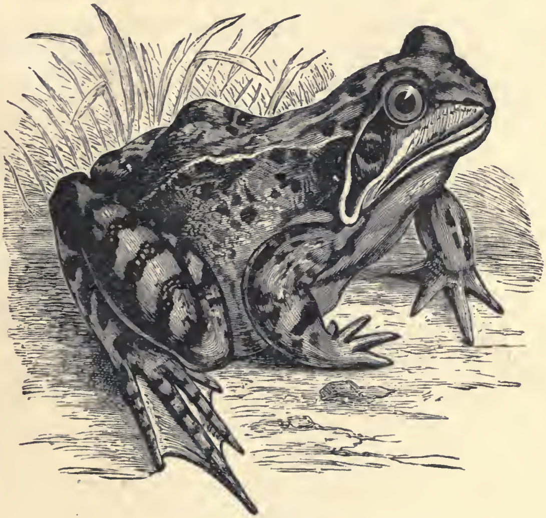

FIG. 246. — **Rana temporaria.** (From Mivart.)

hallux or great toe — is turned inwards or towards the median plane of the body.

The skin is soft and slimy, owing to the secretion of mucous glands; there is no trace of an exoskeleton.

The *vertebral column* (Fig. 247) is remarkable for its extreme shortness; it consists of only nine vertebræ (V. 1–V. 9), the last followed by a slender, bony rod, the *urostyle* (UST). The second to the seventh vertebræ are similar in character. The centrum (B, *cn*) is somewhat depressed, and has a concave anterior and a convex posterior face — a form known as *procœlous*. Each half of the *neural arch* consists of two parts, — a pillar-like *pedicle* (*pd*) springing from the centrum and extending vertically upwards, and a flat, nearly horizontal *lamina* (*lm*), forming, with its fellow, the roof of the neural canal.

The zygapophyses (*a. zyg*) or yoking processes are far better developed than in any fish. Laterally the neural arch gives off on each side a large outstanding *transverse process* (*tr. pr*); its crown is produced into a very small and inconspicuous *neural spine*. The first or *cervical vertebra* (V. 1) has a very small centrum and no transverse processes. There are no anterior zygapophyses, but at the junction of centrum and arch there occurs on each side a large oval concave facet for articulation with one of the condyles of the skull (see p. 411). The eighth vertebra has a biconcave centrum; that of the ninth or *sacral vertebra* (V. 9) is convex in front and presents posteriorly a double convexity articulating with a double concavity on the anterior end of the urostyle.

The *skull* (Figs. 247, 248) consists of a narrow *brain-case*, produced behind into great outstanding *auditory capsules*, and in front into large *olfactory capsules*. The whole of the bones of the *upper jaw* are immovably fixed to the cranium so that the only free parts are the *lower jaw* and a small plate, the *hyoid apparatus*, partly bony and partly cartilaginous, which supports the tongue, and is the sole representative of the entire visceral or gill-bearing skeleton of the fishes.

A cartilaginous cranium comparable with that of the dogfish, but very thin and delicate, forms the foundation of the skull of the frog; but superadded to this are a number of *cartilage bones* — or bones which replace portions of the cartilage, and *membrane bones* — or bones which are formed in membrane, independently of the cartilage. There are five cartilage bones, the paired *exoccipitals* and *pro-otics*, and the median *sphenethmoid*. The exoccipitals (EX. OC) lie in the posterior or *occipital* region of the skull and bound the large opening or *foramen magnum* (*for. mag*) at the posterior end of the skull through which the spinal cord, contained in the neural canal enclosed by the neural arches of the vertebræ, becomes continuous with the brain, contained in the cavity of the cranium. Below the foramen magnum are a pair of oval projections, the *occipital condyles* (*oc. cn*), for articulation with the first vertebra of the spinal column. The second pair of cartilage bones, the *pro-otics* (PR. OT), are ossifications in the roof of the auditory capsule, situated just in front of the exoccipitals, with which they become firmly united. The sphenethmoid (SP. ETH) is a peculiar ossification of somewhat complex form, which lies partly in the wall of the anterior portion of the cranial cavity, partly in the wall of the posterior portions of the nasal cavities or olfactory sacs.

To this cartilaginous cranium with its cartilage bones certain membrane bones are added. Covering the roof of the brain-case are two long narrow bones called the *fronto-parietals* (*FR. PA*), because they are formed by the

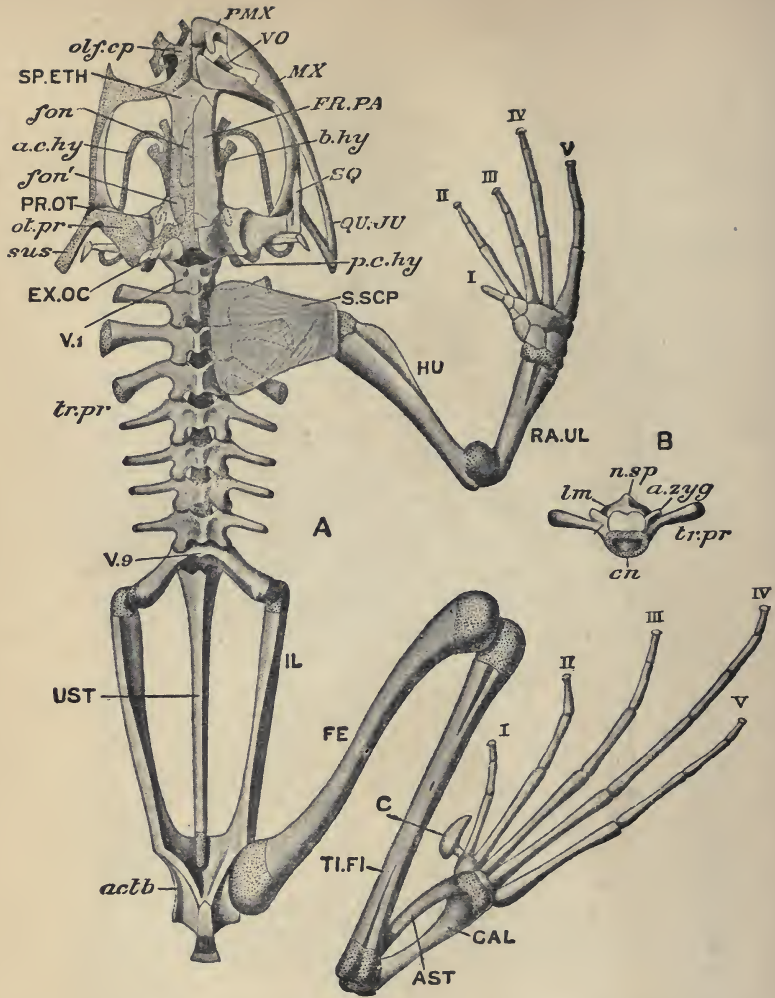
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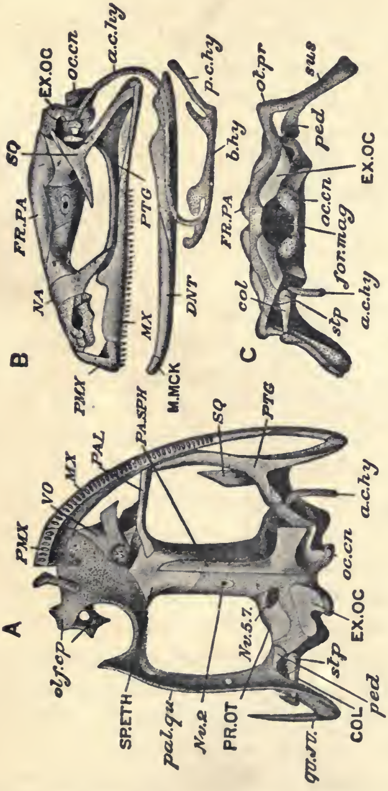
FIG. 247. — **Rana temporaria.** A, the skeleton from the dorsal aspect; the left half of the shoulder girdle and the left fore and hind limbs are removed, as also are the membrane bones on the left side of the skull. Cartilaginous parts dotted. Names of cartilage bones in thick, those of membrane bones in italic capitals. *a. c. hy*, anterior cornu of hyoid; *actb*, acetabulum; **AST**, astragalus; *b. hy*, basi-hyal; **C**, calcar; **CAL**, calcaneum; **EX. OC**, ex-occipital; **FE**, femur; *fon. fon'*, fontanelles; *FR. PA*, fronto-parietal; **HU**, humerus; **IL**, ilium; *MX*, maxilla; *ol. cp*, olfactory capsule; *ct pr*, otic process; *p. c. hy*, posterior cornu of hyoid; *PMX*, premaxilla; **PR. OT**, pro-otic; **RA. UL**, radio-ulna; **SP. ETH**, sphenethmoid; *SQ*, squamosal; **S. SCP**, supra-scapula; *sus*, suspensorium; **TI. FI**, tibio-fibula; *tr. pr*, transverse process: **UST**, urostyle; **V. 1**, cervical vertebra; **V. 9**, sacral vertebra; *VO*, vomer; *I–V* digits. B, the fourth vertebra, anterior face. *a. zyg*, anterior zygapophysis; *cn.* centrum; *lm*, lamina; *n. sp*, neural spine; *pd*, pedicle; *tr. pr*, transverse process. (After Howes, slightly altered.)

union of a pair of *frontals* in front with a pair of *parietals* behind. Over the olfactory capsules are a pair of triangular *nasals* (*NA*), and applied to their ventral surfaces small paired *vomers* (*VO*). On the ventral surface of the skull is a large T-shaped *parasphenoid* (*PA. SPH*), its stem underlying the base of the cranium, while its two arms extend outwards beneath the auditory capsules.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MX
PTG
M.MCK
DNT
p.c.hy
b.hy
C
col
stp
a.c.hy
for.mag
FR.PA
oc.cn
EX.OC
ped
ot.pr
sus

Fig. 248. — **Rana temporaria.** The skull. A, from beneath, with the membrane bones removed on the right side (left of figure); B, from the left side, with mandible and hyoid; C, from behind. *a. c. hy*, anterior cornu of hyoid; *b. hy*, body of hyoid; **COL**, columella; *DNT*, dentary; **EX. OC**, exoccipital; *for. mag*, foramen magnum; *FR. PA*, fronto-parietal; **M. MCK**, mento-meckelian; *MX*, maxilla; *NA*, nasal; *Nv. 2*, optic foramen; *Nv. 5, 7*, foramen for fifth and seventh nerves; *oc. cn*, occipital condyle; *olf. cp*, olfactory capsule; *ot. pr*, otic process; *PAL*, palatine; *pal. qu*, palato-quadrate; *PA. SPH*, parasphenoid; *p. c. hy*, posterior cornu of hyoid; *ped*, pedicle; *PMX*, pre-maxilla; **PR. OT**, pro-otic; *PTG*, pterygoid; *QU. JU*, quadrato-jugal; **SP. ETH**, sphenethmoid; *SQ*, squamosal; *stp*, stapes; *VO*, vomer. (After Howes, slightly altered.)

The palato-quadrate cartilage is unossified; but in relation to its anterior portion is a *palatine* (*PAL*) membrane bone and to its posterior portion a *pterygoid* (*PTG*). The former is a slender rod-like bone directed transversely on the lower surface of the skull. The latter is a larger three-rayed bone, having an anterior, an inner, and a posterior arm. The posterior portion of the palato-quadrate cartilage, the *quadrate* or *suspensorium* (*sus*), connects the lower jaw with the posterior region of the skull. Internally it is covered over by the inner and posterior arm of the pterygoid; externally a hammer-shaped membrane bone, the *squamosal* (*SQ*) is applied to it. The upper jaw is formed by three membrane bones, the small *premaxilla* (*PMX*) in front, then the long narrow *maxilla* (*MX*), and finally the short *quadrato-jugal* (*QU. JU*) which is connected posteriorly with the quadrate. The mandible contains on each side a persistent Meckel's cartilage as a sort of core, ossified at its anterior end, outside which are two membrane bones. The hyoid is a squarish plate of cartilage (*b. hy*) with two pairs of processes (*a. c. hy*, *p. c. hy*), the posterior of which is ossified.

The *scapula* is ossified and is connected by its dorsal edge with a *supra-scapula* (Fig. 247, S. SCP) formed partly of bone, partly of calcified cartilage, and developed from the dorsal region of the embryonic shoulder-girdle. The *coracoid* (Fig. 249, *Co*) is also ossified, while the *procoracoid* is represented by a bar of cartilage, having a membrane bone, the *clavicle* (*Cl*), closely applied to it. The supra-scapula overlaps the anterior vertebræ; the coracoid and procoracoid are connected ventrally by a cartilage, the *epicoracoid* (*Co′*), which is in close contact with its fellow of the opposite side in the middle ventral line, so that the entire shoulder-girdle, like that of the dogfish, forms a single inverted arch.

Passing forwards from the anterior ends of the united epicoracoids is a rod of bone, the *episternum* (*Ep*), tipped by a rounded plate of cartilage, the *omosternum ;* and passing backwards from their posterior ends is a similar but larger bony rod, the *sternum* (*St*), also tipped by a cartilaginous plate, to which the name *xiphisternum* (*Kn*) is applied.

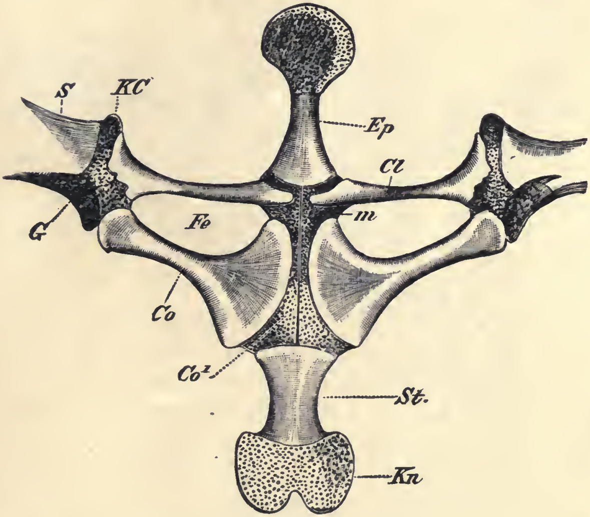


FIG. 249. — **Rana esculenta.** The shoulder girdle from the ventral aspect. *Co*, coracoid; *Co'*, epicoracoid; *Cl*, clavicle; *G*, glenoid cavity; *Ep*, episternum; *Fe*, fenestra between procoracoid and coracoid; *KC*, cartilage separating scapula and clavicle; *Kn*, xiphisternum; *m*, junction of epicoracoids; *S*, scapula; *St*, sternum. (From Wiedersheim's *Comparative Anatomy.*)

The four limbs deviate from the typical structure (p. 341) chiefly in the fusion of the radius and ulna into a single *radio-ulna* (Fig. 247, RA. UL) and in the presence of only four complete digits with a vestigial one on the radial side. In all probability the latter represents the pollex, and the complete digits are the second to the fifth of the typical hand. Six carpals only are present.

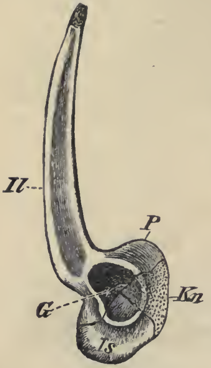
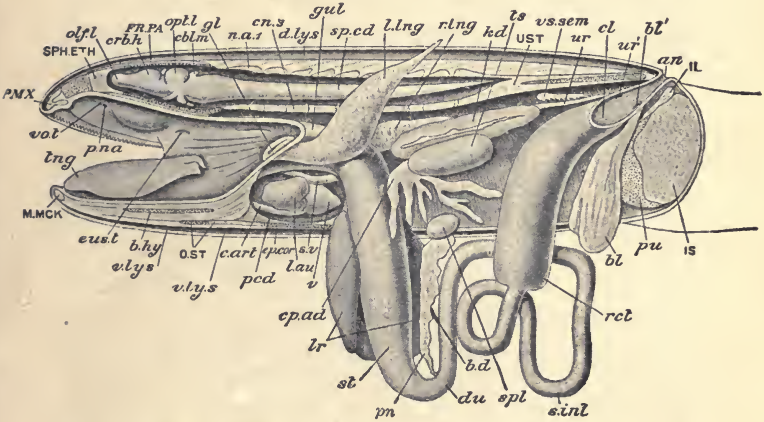


FIG. 250. — **Rana esculenta.** Pelvic girdle from the right side. *G*, acetabulum; *Il*, *P*, ilium; *Is*, ischium; *Kn*, pubis. (From Wiedersheim's *Comparative Anatomy.*)

The *pelvic arch* (Figs. 247 and 250) is very peculiarly modified; it resembles in form a bird's "merry-thought," consisting of two long curved bars articulating in front with the transverse processes of the sacral vertebra and uniting posteriorly in an irregular vertical disc of mingled bone and cartilage which bears on each side a deep, hemispherical *acetabulum* (Fig. 250, *G*) for the articulation of the thigh-bone. The curved rods are the *ilia* (*Il*, *P*); they expand posteriorly and unite with one another in the median plane to form the dorsal portion of the disc and about one-half of the acetabulum. The posterior portions of the disc and the acetabulum are furnished by the *ischia* (*Is*), fused with one another in the sagittal plane, and their ventral portions by the similarly united *pubes* (*Kn*). The ilium and ischium are formed of true bone, the pubis of calcified cartilage; the union of the elements in the median plane is called the *symphysis*. In the *hind-limb* the tibia and fibula are fused to form a single *tibio-fibula* (Fig. 247, TI. FI), and the two bones in the proximal row of the tarsus, namely, the tibiale or *astragalus* (AST) and the fibulare or *calcaneum* (CAL), are greatly elongated and provide the leg with an additional segment. There are three tarsals in the distal row, one of which appears to represent a central, another the first distal carpal, and the third the fused second and third. There are five well-developed digits, and on the tibial side of the first is a spur-like structure or *calcar* (*C*), formed of three bones, a metatarsal and two phalanges: such a rudimentary digit is called a *pre-hallux*.

The mouth leads into a wide *buccal cavity* having in its roof the *posterior nares* (Fig. 251, *p. na*), a pair of projections due to the downward bulging of the large eyes, and the *Eustachian tubes* (*eus. t*, *vide infra*). On its floor is the large *tongue* (*tng*), attached in front and free behind, where it ends in a double point; by means of its muscles it can be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SPH.ETH
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p.na
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eus.t
b.hy
v.lys
O.ST
c.art
epcor
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spl
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rct
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pu
IS

FIG 251.—**Rana temporaria**. Dissection from the left side; the viscera somewhat displaced. *an*, anus; *b. d*, bile duct; *b. hy*, body of hyoid; *bl*, urinary bladder; *bl'*, its opening into cloaca; *c art*, conus arteriosus; *cblm*, cerebellum; *cl*, cloaca; *cn. 3*, centrum of third vertebra; *cp. ad*, corpus adiposum; *crb. h*, cerebral hemisphere; *d. ly. s*, dorsal lymph sinus; *du*, duodenum; *ep. cor*, epicoracoid; *eus. t*, Eustachian tube; *FR. PA*, fronto-parietal; *gl*, glottis; *gul*, gullet; IL, ilium; IS, ischium; *kd*, kidney; *l. au*, left auricle; *l. lng*, left lung; *lr*, liver; M. MCK, mento-meckelian; *n. a. 1*, neural arch of first vertebra; *olf. l*, olfactory lobe; *opt l*, optic lobe; O. ST, omo- and epi-sternum; *pcd*, pericardium; *PMX*, premaxilla; *pn*, pancreas; *p na*, posterior naris; *pu*, pubis; *rct*, rectum; *r. lng*, right lung; *s. int*, small intestine; *sp. cd*, spinal cord; SPH. ETH, sphenethmoid; *spl*, spleen; *st*, stomach; *s. v*, sinus venosus; *tng*, tongue; *ts*, testis; *ur*, ureter; *ur'*, its aperture into the cloaca; UST, urostyle; *v*, ventricle; *v ly. s*, ventral lymph sinus; *vo. t*, vomerine teeth; *vs. sem*, vesicula seminalis.

suddenly projected, point foremost, from the mouth, and is used in the capture of insects. Immediately behind the tongue is the *glottis* (*gl*). *Teeth* are arranged in a single series round the edge of the upper jaw, attached to the premaxillæ and maxillæ; there is also a small patch of teeth (*vo. t*) on each vomer just internal to the posterior nostril. The teeth are small conical bodies, their bases ankylosed to the bones; their only use is to prevent the polished or slimy bodies of the prey—insects and worms—from slipping out of the mouth.

The buccal cavity narrows towards the *pharynx*, which leads by a short *gullet* (*gul*) into a *stomach* (*st*) consisting of a wide cardiac and a short, narrow pyloric division. The *duodenum* (*du*), or first portion of the *small intestine*, passes forwards parallel with the stomach; the rest of the small intestine is twisted into a coil. The large intestine or *rectum* (*rct*) is very wide and short, and passes without change of diameter into the cloaca (*cl*).

The *liver* (*lr*) is two-lobed; between the right and left lobes lies a large *gall-bladder*. The *pancreas* (*pn*) is an irregular gland surrounding the bile duct, into which it pours its secretion; the *spleen* (*spl*) is a small, red globular body attached near the anterior end of the rectum.

The *lungs* (*l. lng*, *r. lng*) are elastic sacs lying in the anterior part of the cœlom above the heart and liver; their size and appearance vary greatly according to their state of distention. Each contains a spacious cavity, and has its walls raised into a complete network of ridges abundantly supplied with blood-vessels. The two lungs open anteriorly into a small *laryngo-tracheal chamber* which communicates with the mouth by the narrow slit-like *glottis*. The walls of the laryngo-tracheal chamber are supported by a cartilaginous framework, and its mucous membrane is raised into a pair of horizontal folds, the *vocal chords*, by the vibration of which the croak of the frog is produced.

In breathing, the frog keeps its mouth closed, and, by depressing the floor of the mouth draws air into the buccal cavity through the nostrils. The floor of the mouth is then raised, the nostrils are closed, and the air is forced through the glottis into the lungs. The skin is also an important respiratory organ.

The *pericardium* (Fig. 251, *pcd*) is not a separate chamber, as in fishes, but the heart, enclosed in a pericardial membrane, lies in the general cœlomic cavity between the gullet above and the epicoracoids below. The heart consists of a sinus venosus (Figs. 251 and 252, *s. v*), right and left auricles (*r. au*, *l. au*), a ventricle (*v*, *vt*), and a conus arteriosus (*c. art*). As in Dipnoi, the sinus venosus opens into the right auricle, the pulmonary veins into the left; a striking advance is seen in the greatly increased size of the left auricle and its separation by a complete partition, the *septum auricularum* (Fig. 252, *spt. aur*), from the right. The two auricles open by a common auriculo-ventricular aperture, guarded by a pair of valves (*au. v. v*), into the single ventricle. The conus springs from the right side of the base of the ventricle; it is separated from the latter by three small semilunar valves, and is traversed obliquely along its whole length by a large flap-like longitudinal valve (*lv*) which springs from its dorsal wall and is free ventrally. The conus passes without change of diameter into a *bulbus aortæ*, the two being separated by a semilunar valve and by the free end of the longitudinal valve. The bulbus gives off two branches, right and left, each of them divided by two longitudinal partitions into three vessels, — an inner or anterior, the *carotid trunk* (*car. tr*), a middle, the *systemic trunk* or *aortic arch*, and an outer or posterior, the *pulmo-cutaneous* *trunk* (*pul. cu. tr*). The carotid and systemic trunks communicate separately with the bulbus, the two pulmo-cutaneous trunks communicate with the anterior end of the conus by a single aperture placed just below the free end of the longitudinal valve.

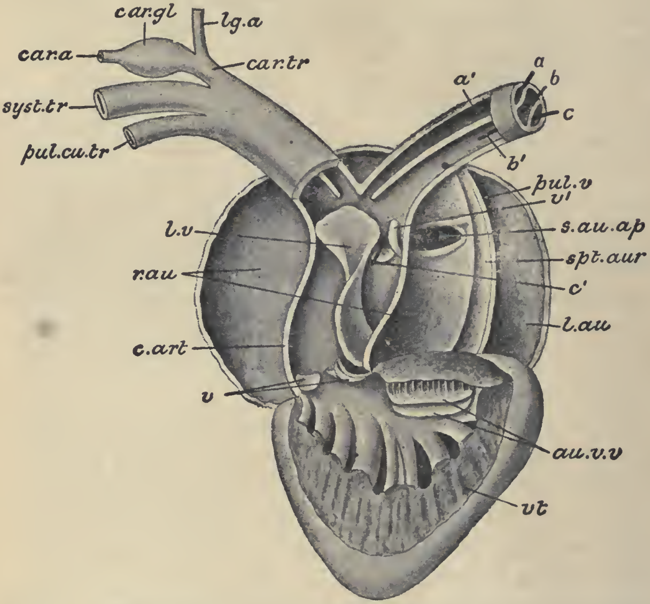

FIG. 252.—**Rana temporaria.** The heart from the ventral aspect with the cavities laid open. *a*, *a'*, bristle in left carotid trunk; *au. v. v*, auriculo-ventricular valves; *b*, *b'*, bristle in left systemic trunk; *c*, *c'*, bristle in left pulmo-cutaneous trunk; *car. a*, carotid artery; *car. gl*, carotid plexus; *c. art*, conus arteriosus; *car. tr*, carotid trunk; *l. au*, left auricle; *lg. a*, lingual artery; *l. v*, longitudinal valve; *pul. cu tr*, pulmo-cutaneous trunk; *pul v*, aperture of pulmonary veins; *r. au*, right auricle; *s. au. ap*, sinu-auricular aperture; *spt. aur*, septum auricularum; *v. v'*, valves; *vt*, ventricle.

After being bound together in the way described for a short distance, the carotid, systemic, and pulmo-cutaneous trunks separate from one another. The carotid trunk divides

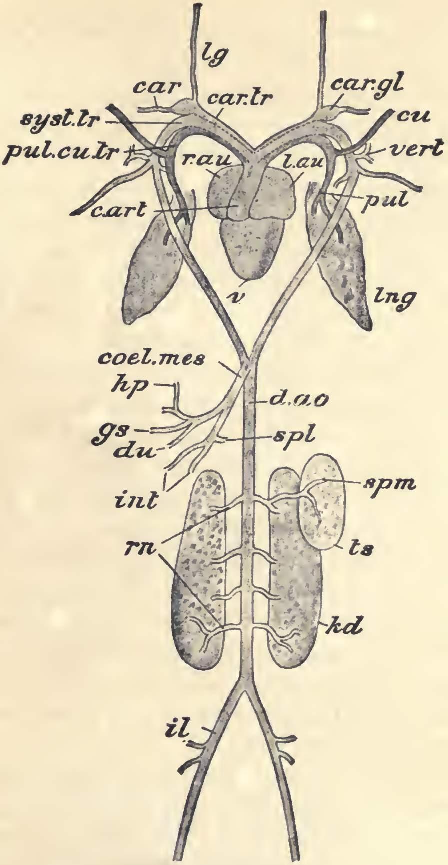
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FIG. 253. — **Rana temporaria.** The arterial system, with the heart, lungs, kidneys, and left testis, from the ventral aspect. *car*, carotid artery; *car. gl*, carotid gland; *c. art*, conus arteriosus; *car. tr*, carotid trunk; *cœl. mes*, cœliaco-mesenteric artery; *cu*, cutaneous artery; *d. ao*, dorsal aorta; *du*, duodenal artery; *gs*, gastric artery; *hp*, hepatic artery; *il*, iliac artery; *int*, intestinal arteries; *kd*, kidney; *l. au*, left auricle; *lg*, lingual artery; *pul*, pulmonary artery; *pul. cu. tr*, pulmo-cutaneous trunk; *r. au*, right auricle; *rn*, renal arteries; *spl*, splenic artery; *sys. tr*, systemic trunk; *spm*, spermatic artery; *ts*, testis; *v*, ventricle.

into *carotid* (Figs. 252, *car. a* and 253, *car*) and *lingual* (*lg*) *arteries* for the supply of the head, the former having at its base a small swelling, the *carotid gland* (*car. gl*), consisting of a plexus of blood-vessels. The systemic trunks curve round the gullet and unite with one another above it to form the *dorsal aorta* (*d. ao*), from which, or from one of the systemic trunks themselves, the arteries to all parts of the body, except the head, the lungs, and the skin, are given off. The pulmo-cutaneous trunk divides into two, a *pulmonary artery* (*pul*) to the lung, and a *cutaneous artery* (*cu*) to the skin.

The blood from the head and fore-limbs is returned by veins which unite to form a pair of large trunks, the *precavals*, which open separately into the sinus venosus.

One portion of the blood from the hind-limb is carried forward by a vein which unites with its fellow of the opposite side to form the *abdominal vein* (Fig. 254, *abd*), which passes forwards, in the ventral body-wall, to the level of the sternum, where it turns inwards and divides into two branches, both breaking up into capillaries in the liver. Just as it enters the liver it is joined by the *hepatic portal vein* (*hp. pt*), bringing the blood from the stomach, intestine, spleen, and pancreas. The rest of the blood from the hind-limb is carried by the *renal portal* vein to the corresponding kidney.

The blood is collected from the kidneys by the *renal veins* (*rn*), which unite to form the large unpaired *post-caval vein* (*pt. cv*). This passes forward through a notch in the liver, receives the *hepatic veins* (*hp*) from that organ, and finally opens into the sinus venosus. Thus the blood from the hind-limbs has to pass through one of the two portal systems on its way back to the heart; part of it goes by the renal portal veins to the kidneys, and thence by the renal veins to the post-caval, part by the abdominal vein to the liver, and thence by the hepatic veins to the post-caval. Lastly, the blood which has been purified in the lungs is returned by the *pulmonary veins* (*pul*) directly to the left auricle.

It will be perceived that the blood poured into the right auricle is mostly impure or venous, that poured into the left fully aërated or arterial. When the auricles contract, which they do simultaneously, each passes its blood into the corresponding part of the ventricle, which then instantly contracts, before the venous and arterial bloods have time to mix. Since the conus arteriosus springs from the right side of the ventricle, it will at first receive only venous blood, which, on the contraction of the conus, might pass either into the bulbus aortæ or into the aperture of the pulmo-cutaneous trunks. But the carotid and systemic trunks are connected with a much more extensive capillary system than the pulmo-cutaneous, and the pressure in them is proportionally great, so that it is easier for the blood to enter the pulmo-cutaneous trunks than to force aside the valves between the conus and the bulbus. A fraction of a second is, however, enough to get up the pressure in the pulmonary and cutaneous arteries, and in the meantime the pressure in the arteries of the head, trunk, etc., is constantly diminishing, owing to the continual flow of blood towards the capillaries. Very soon, therefore, the blood forces the valves aside and makes its way into the bulbus aortæ. Here again the course taken is that of least resistance; owing to the presence of the carotid gland the passage of blood into the carotid trunks is less free than into the wide, elastic, systemic trunks. These will, therefore, receive the next portion of blood, which, the venous blood having been mostly driven to the lungs, will be a mixture of venous and

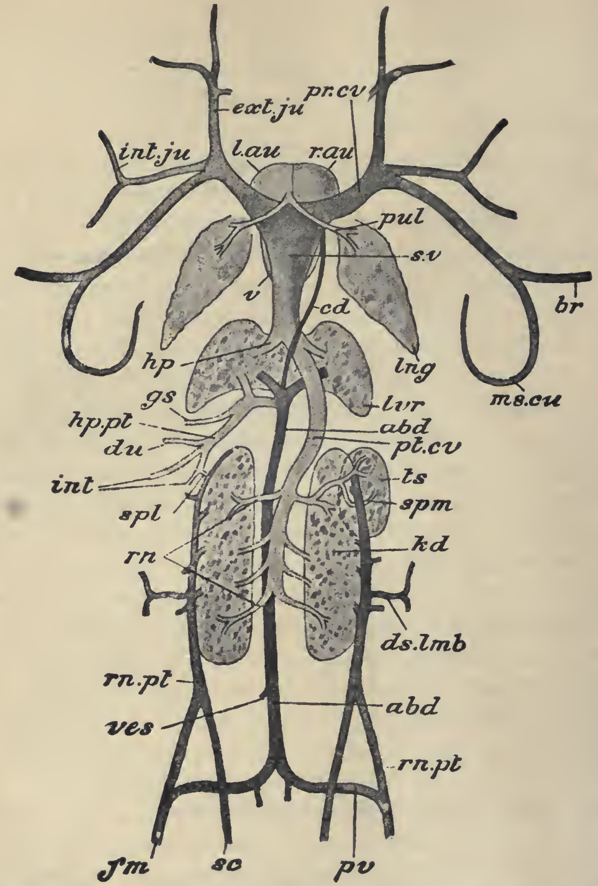
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FIG. 254.—**Rana temporaria.** The venous system with the heart, lungs, liver, kidneys, and right testis, from the dorsal aspect. *abd*, abdominal vein; *br*, brachial vein; *cd*, cardiac vein; *ds. lmb*, dorso-lumbar vein; *du*, duodenal vein; *ext. ju*, external jugular vein; *fm*, femoral vein; *gs*, gastric vein; *hp*, hepatic vein; *hp. pt*, hepatic portal vein; *int*, intestinal veins; *int. ju*, internal jugular vein; *kd*, kidney; *l. au*, left auricle; *lng*, lung; *lvr*, liver; *ms. cu*, musculo-cutaneous vein; *pr. cv*, pre-caval vein; *pt. cv*, post-caval vein; *pul*, pulmonary vein; *pv*, pelvic vein; *r. au*, right auricle; *rn*, renal veins; *rn. pt*, renal portal vein; *sc*, sciatic vein; *spl*, splenic vein; *spm*, spermatic vein; *s. v*, sinus venosus; *ts*, testis; *ves*, vesical veins.

arterial. Finally, as the pressure rises in the systemic trunks, the last portion of blood from the ventricle, which, coming from the left side, is arterial, will pass into the carotids and so supply the head.

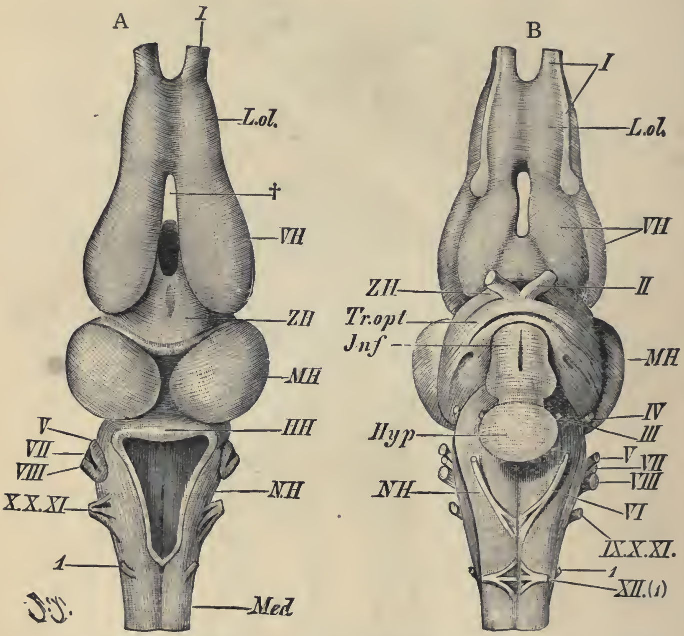
The *lymphatic system* is very well developed, and is remarkable for the dilatation of many of its vessels into immense *lymph sinuses*. The lymph is pumped into the veins by two pairs of *lymph-hearts*, one situated beneath the supra-scapulæ, the other beside the posterior end of the urostyle.

The *brain* (Fig. 255) has a very small cerebellum (*H H*), large optic lobes (*M H*), a well-developed diencephalon, and large hemispheres and olfactory lobes, the latter fused in the median plane.

The first spinal nerve performs the function of the *hypoglossal*, one of the cranial nerves of higher Vertebrates supplying the muscles of the tongue: it passes out between the first and second vertebræ. The spinal cord is short, and ends in a delicate filament, the *filum terminale*. In correspondence with the number of vertebræ there are only ten pairs of spinal nerves, of which the second and third unite to form a *brachial plexus* giving off the nerves to the fore-limb, while the seventh to the tenth join to form a *lumbo-sacral plexus* giving off the nerves to the hind-limb.

The *olfactory sacs* have each two openings: the *anterior naris* or external nostril and the *posterior naris* (Fig. 251, *p. na*), or internal nostril, which opens into the mouth immediately external to the vomer.

The *eye* and the *auditory organ* have the usual structure, but in connection with the latter there is an important accessory organ of hearing not hitherto met with. Bounded externally by the tympanic membrane, and internally by the outer wall of the auditory capsule, is a considerable space, the *tympanic cavity* (*cav*), which communicates with the mouth by the short Eustachian tube already noticed (Fig. 251, *eus. t*), so that a probe thrust through the tympanic membrane from outside passes directly into the mouth. In the roof of the tympanic cavity lies a slender rod of bone and cartilage, the *columella*, its head, or extra-columella, attached to the inner surface of the tympanic membrane, its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IV
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Hyp
V
VII
VIII
NH
VI
IX.X.XI.
1
XII.(1)

FIG. 255.—**Rana esculenta.** The brain. A, from above; B, from below. *ch. opt*, optic chiasma; *HH*, cerebellum; *Hyp*, pituitary body; *Inf*, infundibulum; *L. ol*, olfactory lobe; *Med*, spinal cord; *MH*, mid brain; *NH*, medulla oblongata; *Th. opt*, optic thalamus; *Tr. opt*, optic tract; *VH*, cerebral hemisphere; *ZH*, diencephalon; *I—X*, cerebral nerves; *XII.* (*1*), hypoglossal (first spinal) nerve. (From Wiedersheim's *Comparative Anatomy*.)

handle united to the *stapes*, a nodule of cartilage which is fixed in the membrane of the *fenestra ovalis* (p. 358). Sonorous vibrations striking the tympanic membrane are communicated by the columella and stapes to the fenestra ovalis, thence to the perilymph, and thence to the membranous labyrinth. The connection of the Eustachian tube with the mouth obviates undue compression of the air in the tympanic cavity.

The *kidneys* (Figs. 251 and 253, *Kd*, and Figs. 256 and 257, *N*) are flat, somewhat oval bodies of a dark red colour, lying in the posterior region of the cœlom. On the ventral face of each is an elongated, yellow *adrenal*, and irregularly scattered *nephrostomes* occur on the same surface. They do not, however, communicate with the urinary tubules, but with the renal veins, and serve to propel the lymph from the cœlom to the venous system. The *ureters* (*Ur*) pass backwards from the outer borders of the kidney, and open into the dorsal wall of the cloaca (*Cl*).

Opening into the cloaca on its ventral side is a bilobed, thin-walled, and very delicate sac, the *urinary bladder* (Fig. 251, *bl*), into which the urine passes by gravitation from the cloaca when the anus is closed.

The *testes* (Fig. 256, *Ho*) are white ovoid bodies lying immediately ventral to the anterior ends of the kidneys, to which they are attached by folds of peritoneum. From the inner edge of each pass a number of delicate *vasa efferentia*, which enter the kidney and become connected with the urinary tubules. The spermatic fluid is thus passed into the urinary tubules and carried off by the ureter, which is therefore a urinogenital duct in the male frog. A *vesicula seminalis* opens by numerous small ducts into the outer side of the ureter. Attached to the testis are lobed bodies of a bright yellow colour, the *fat-bodies* (*FK*).

The *ovaries* (Fig. 257, *Ov*) are large folded sacs, on the surface of which the black and white ova project. A fat-body is attached to each. The *oviducts* (*Od*) are greatly convoluted tubes, the narrow anterior ends of which open into the cœlom by small apertures (*Ot*) placed close to the bases of the lungs. Their posterior ends are wide and thin-walled (*Ut*), and open into the cloaca (*P*). The ova break loose from the surface of the ovary and enter the cœlomic apertures of the oviducts, the walls of which are glandular, and secrete an albuminous fluid having the property of swelling up in water. The eggs receive a coating of this substance as they pass down the oviducts, and are finally stored up in the thin-walled posterior portions of those tubes, which in the breeding season become immensely dilated and serve as uteri. The eggs are laid in water in large masses; each has one black and one white hemisphere, the former always directed upwards, and is surrounded by a sphere of jelly. During oviposition the male sheds his spermatic fluid over the eggs, and the sperms making their way through the jelly impregnate them.

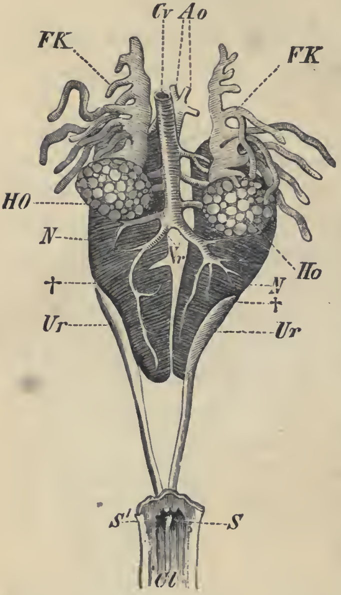

FIG. 256. — **Rana esculenta.** Urinogenital organs of the male. *Ao*, dorsal aorta; *Cl*, cloaca; *Cv*, post-caval vein; *FK*, fat bodies; *HO*, testes; *N*, kidneys; *S*, apertures of ureters into cloaca; *Ur*, ureters. (From Wiedersheim's *Comparative Anatomy*.)

When the embryo escapes from the egg by the rupture of the egg-membrane it swims about as a little fish-like creature or *tadpole*, with two pairs of branched external gills and a long tail. There is no mouth, and eyes have not yet become developed. On the lower surface of the head is a pair of

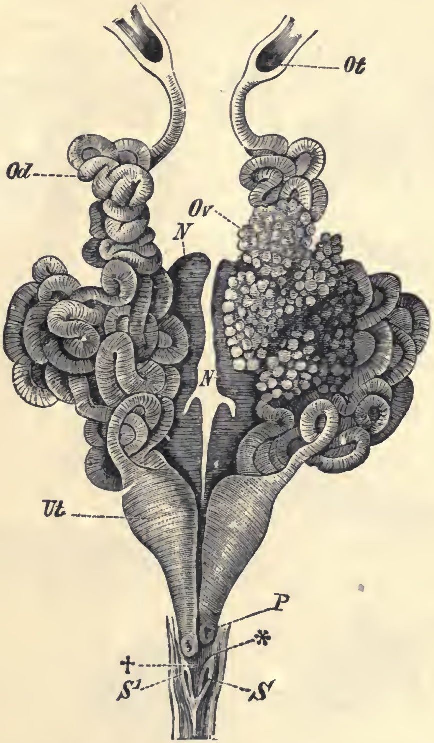

FIG. 257.—**Rana esculenta.** Urinogenital organs of the female. *N*, kidneys; *Od*, oviduct; *Ot*, its cœlomic aperture; *Ov*, left ovary (the right is removed); *P*, cloacal aperture of oviduct; *S. S'*, cloacal apertures of ureters; *Ut*, uterine dilatation of oviduct. (From Wiedersheim's *Comparative Anatomy*.)

suckers by which the tadpole is able to attach itself to water-weeds. Soon a pair of external gills appears, the mouth and gill-slits are formed, and the eyes appear. The mouth is small, bounded by lips beset with horny papillæ, and provided with a pair of horny jaws. The enteric canal grows to a great length and is coiled like a watch-spring, and the tadpole browses upon the water-weeds which form its

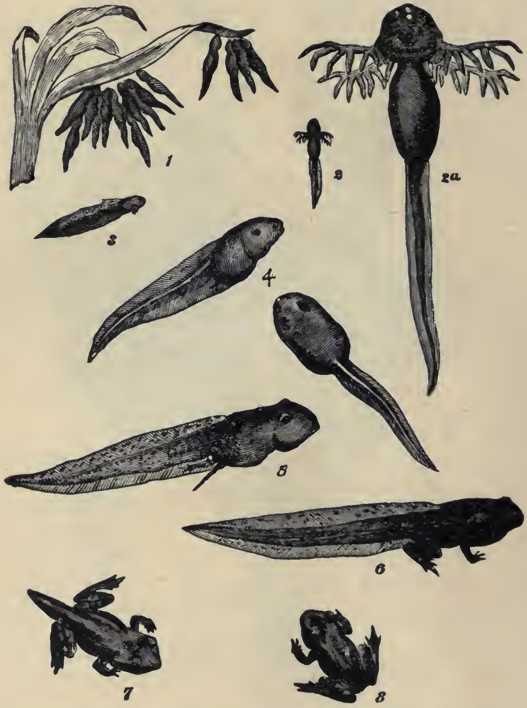

FIG. 258.—**Rana temporaria**. Stages in the life-history, from the newly-hatched Tadpoles (*1*) to the young Frog (*8*). *2a* is a magnified view of *2*. (From Mivart.)

staple food, though it also eats decaying leaves and the flesh of dead animals.

Soon the external gills show signs of shrivelling, and at the same time *internal gills*, like those of fishes, are developed on the branchial arches. A fold of skin, the *operculum*, appears on each side, in front of the gills, growing from the region of the hyoid arch, and extends backwards until the gill-slits and external gills are covered and there is only a single small external branchial aperture on each side. On the right side the operculum soon unites with the body-wall so as to close the branchial aperture, but on the left side the opening remains for a considerable time as the sole exit of the water. At this time the tadpole is to all intents and purposes a fish.

The lungs now appear, and the larva is for a time truly amphibious, rising periodically to the surface to breathe air; the single branchial aperture, however, soon closes, and henceforth respiration is purely aërial.

In the meantime the limbs are developed. The hind-limbs appear as little rounded buds, one on each side of the root of the tail. The fore-limbs arise beneath the operculum, and are therefore hidden at first; soon, however, they emerge by forcing their way through the operculum. As the limbs increase in size, the tail undergoes a progressive shrinking. The mouth widens, the intestine undergoes a relative diminution in length, and vegetable is exchanged for animal diet. The little tailed frog can now leave the water and hop about upon land; its tail is soon completely absorbed, and the metamorphosis is complete.

The frogs and toads are all closely allied as regards all the main features of their structure — the chief differences between the many genera and species being in such superficial characteristics as coloration and proportions. In some teeth are altogether absent; in others the webs between the toes are not developed; in some tree-frogs (*Hyla* and allied genera) the toes terminate in sucking discs. A less superficial point of divergence from the structure of the common American frogs is to be observed in some members of the group, such as the tree-frogs and toads (*Hyla*, *Bufo*, and others), in which the two halves of the shoulder-girdle, instead of being firmly united in the middle line, overlap one another. In one small group the tongue is absent. In some, again, there is no fish-like, gill-bearing larva or tadpole — the young animal emerging from the egg with the limbs formed, with no gills and no tail. All the frogs and toads are grouped together to form an order of Amphibia — the Anura or tailless Amphibia.

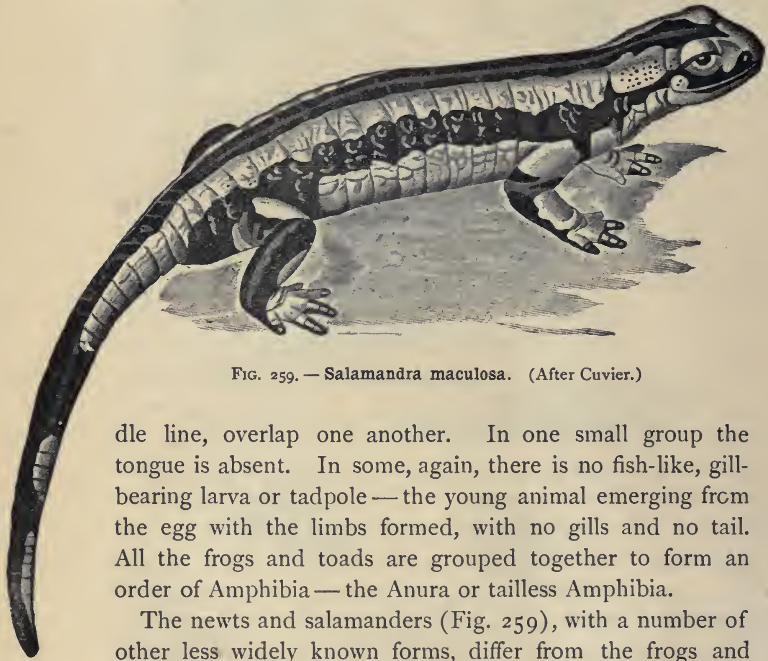

FIG. 259. — **Salamandra maculosa.** (After Cuvier.)

The newts and salamanders (Fig. 259), with a number of other less widely known forms, differ from the frogs and toads in the possession in the adult of a well-developed tail. These constitute the order Urodela or tailed Amphibians. Of these tailed Amphibians, some, such as the newts and salamanders, lose both gills and gill-slits completely in the adult: while in others (such as *Proteus*, *Necturus*, and *Siren*), either gills are retained throughout life, or, as in the American *Menopoma*, or hell-bender, gill-slits remain as a permanent record of their presence in the larva. In some of the tailed Amphibians the limbs are well-developed; in others they are very small.

Widely different in many respects from both the Anura and Urodela are a group of Amphibia — the *Gymnophiona* — which are quite snake-like in appearance, owing to the elongated and narrow form of the body and the entire absence of limbs. The group is represented by the blind snake (*Cœcilia*) of Central and South America.

CLASS IV. REPTILIA

The class **Reptilia** comprises the lizards and snakes, the tuataras, the turtles and tortoises, and the alligators and crocodiles. On a superficial comparison of these with the Amphibia, it might be inferred that there is a close alliance between the two groups; but this impression becomes weakened when a closer examination is made of the structure and development, and it

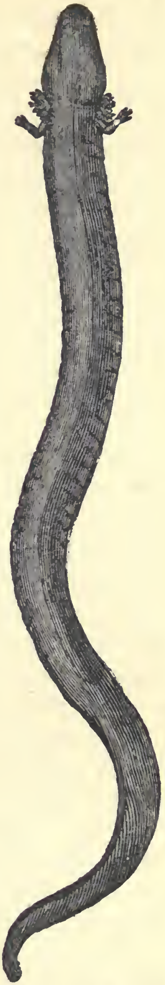

FIG. 260. — Siren lacertina. (From Mivart.)

at length becomes evident that in the Reptilia we have to do with a class of Vertebrates which stand on a distinctly higher plane than the Amphibia. One significant feature of the Reptilia which marks them off sharply from the Amphibia is that the lungs are the sole organs of respiration, gills never being developed at any stage. Another is the development in the embryo of two structures known as the *amnion* and the *allantois*, not developed in lower groups of Vertebrates, but present in the embryos of all the higher. The amnion is a thin membrane which covers over the body of the embryo, the space between it and the latter being tensely filled with a watery fluid. The amnion thus forms a sort of water-cushion, protecting the delicate and fragile embryo from the effects of any shocks which may be sustained by the eggs. The allantois, represented in the frog by the urinary bladder, is a membranous structure developed as a hollow outgrowth of the enteric canal at its posterior end. It becomes highly vascular, and acts as an embryonic respiratory organ.

There are four well-marked orders of living reptiles :—

1. The **Squamata**, comprising the Lacertilia or lizards (including the iguanas, monitors, skinks, geckos, chamæleons, and others), and the Ophidia or snakes (including the vipers and rattlesnakes, pythons, boas, sea-snakes, etc.).

2. The **Rhynchocephalia**, including only the New Zealand Tuatara (*Hatteria*).

3. The **Chelonia**, including the land tortoises, soft tortoises, river and marsh tortoises, and the turtles.

4. The **Crocodilia**, including the crocodiles, gavials, the alligators and caimans.

The most striking external difference between a typical lizard (Fig. 207) and the frog are in the covering of scales in the case of the former, the comparative smallness of its head, and the presence of a distinct neck, the great length of the caudal region, the shortness of the limbs, and the approximate equality in length of the anterior and posterior pairs. The anterior limbs are situated just behind the neck, springing from the trunk towards the ventral surface. The fore-limb, like that of the frog, is divided into three parts, the upper-arm or *brachium*, the fore-arm or *antibrachium*, and the hand or *manus;* there are five digits provided with horny claws, the first digit or pollex being the smallest. The hind-limbs arise from the posterior end of the trunk towards the ventral aspect; each, like that of the frog, consists of three divisions — thigh or *femur*, shank or *crus*, and foot or *pes*. The pes, like the manus, terminates in five clawed digits, of which the first or hallux is the smallest. The head is somewhat pyramidal, slightly depressed; the openings of the external nares are situated above the anterior extremity. The mouth is a wide slit-like aperture running round the anterior border of the head. At the sides are the eyes, each provided with upper and lower opaque movable eyelids, and with a transparent third eyelid or *nictitating membrane*, which, when withdrawn, lies in the anterior angle of the orbit. Behind the eye is a circular brown patch of skin, — the *tympanic membrane*, — corresponding closely to that of the frog, but somewhat sunk below the general level of the skin. The trunk is elongated, strongly convex dorsally, flatter at the sides and ventrally. At the root of the tail on the ventral surface is a slit-like transverse aperture — the *anus* or *cloacal aperture*. The tail is cylindrical, thick in front, gradually tapering to a narrow posterior extremity; it is nearly twice as long as the head and trunk together.

There is an exoskeleton of horny epidermal *scales* covering all parts, differing in size in different positions.

In some groups of lizards the tail is comparatively short and thick; and in others it is depressed and expanded into a leaf-like form. In the chamæleons the long and tapering tail is used as a prehensile organ, the coiling of which round branches of the trees in which the animal lives, aids in maintaining the balance of the body in climbing from branch to branch.

In the limbs there is likewise a considerable amount of variation in the different groups of the Lacertilia. Moderately long pentadactyle limbs, like those of Lacerta, are the rule. In the chamæleons both fore- and hind-limbs become prehensile by a special modification in the arrangement and mode of articulation of the digits. In these remarkable arboreal reptiles the three innermost digits of the manus are joined together throughout their length by a web of skin, and the two outer digits are similarly united; the two sets of digits are so articulated that they can be brought against one another with a grasping movement much analogous to the grasping movements of a parrot's foot or the hand of man. A similar arrangement prevails in the pes, the only difference being that the two innermost and three outermost digits are united. In some groups of Lacertilia, on the other hand, such as the blind-worms (*Anguis*), limbs are entirely absent, or are represented only by mere vestiges; and numerous intermediate gradations exist between these and forms, such as Lacerta, with well-developed limbs. The limbless lizards, such as the glass-snake, and Pygopus (Fig. 261), bear a very close resemblance to the snakes, not only in the absence of the limbs, but also in the general form of the body and the mode of locomotion.

The body of a snake is elongated, narrow, and cylindrical, usually tapering towards the posterior end, sometimes with, more usually without, a constriction behind the head. In the absence of limbs, the beginning of the short caudal region is only indicated by the position of the cloacal opening. The fore-limbs are never represented even by vestiges; in some pythons there are inconspicuous vestiges of hind-limbs, in the form of small claw-like processes. The mouth of the snake is capable of being very widely opened by the free articulation of the lower jaw, and it is this mainly which distinguishes it from the snake-like lizards. But other, less conspicuous, points of distinction are the absence of movable eyelids in the snake, and also the absence of a tympanum.

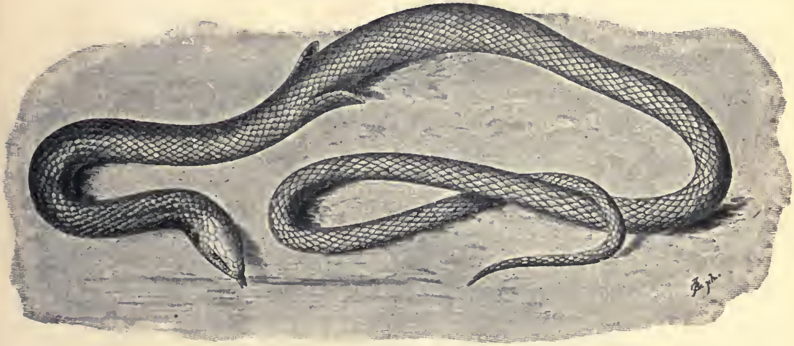

FIG. 261. — **Pygopus lepidopus.** (After Brehm.)

Hatteria, the New Zealand Tuatara (Fig. 262), the only living representative of the Rhynchocephalia, is a lizard-like reptile with a well-developed laterally-compressed tail, and pentadactyle extremities, very similar to those of a typical lizard. The upper surface is covered with small granular scales, and a crest of compressed spine-like scales runs along the middle of the dorsal surface. The lower surface is covered with transverse rows of large squarish plates.

In the Chelonia (Fig. 263) the body is short and broad, enclosed in a hard "shell," consisting of a dorsal part or *carapace* and a ventral part or *plastron*. These are firmly united, apertures being left between them for the head and neck, the tail and the limbs. The neck is long and mobile; the tail short. The limbs are fully developed, though short. In some (land and fresh-water tortoises) they are provided each with five free digits terminating in curved horny claws; in the turtles the digits are closely united together, and the limb assumes the character of a "flipper" or swimming paddle. The cloacal aperture is longitudinal.

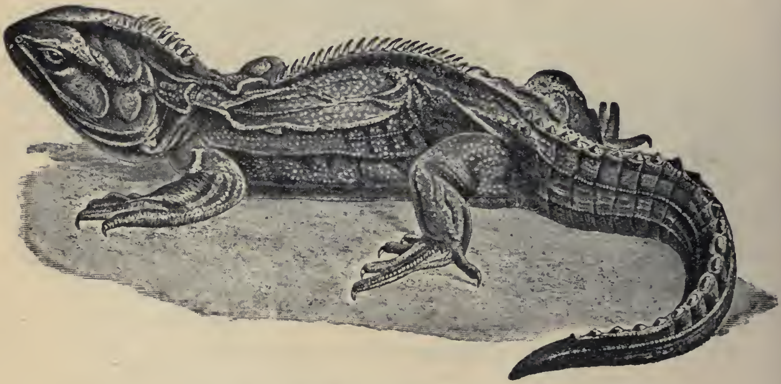

FIG. 262.—**Hatteria punctata.** (After Brehm.)

The Crocodilia, the largest of living reptiles, have the trunk elongated and somewhat depressed, so that its breadth is much greater than its height. The snout is prolonged, the neck short, the tail longer than the body and compressed laterally. The limbs are relatively short and powerful, with five digits in the manus and four in the pes, those of the latter being partly or completely united by webs of skin.

The eyes are very small; the nostrils placed close to the end of the snout and capable of being closed by a sphincter muscle. The cloacal aperture is a longitudinal slit.

Characteristic of the Squamata is the development in the epidermis of horny plates, the *scales*, which cover the entire surface, overlapping one another in an imbricating manner. Sometimes they are similar in character over all parts of the surface; usually there are specially developed scales — the *head shields* — covering the upper surface of the head. In the majority of snakes the ventral surface is covered with a row of large transversely elongated scales, the *ventral shields*. In some lizards (chamæleons and geckos) the scales are reduced and modified into the form of minute tubercles or granules. In some lizards special developments of the scales occur in the form of large tubercles or spines.

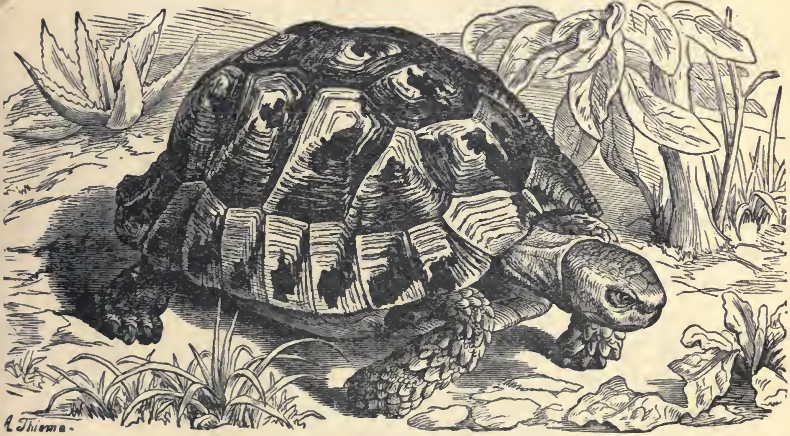

FIG. 263. — Grecian tortoise (**Testudo græca**). (After Brehm.)

In the snake-like Amphisbænians there are no true scales, with the exception of the head shields, but the surface is marked out into annular bands of squarish areas.

In addition to the modification of the scales, the integument of the chamæleons is remarkable for the changes of colour which it undergoes, these changes being due to the presence in the dermis of pigment cells which contract or expand under the influence of the nervous system, in a way that reminds one of the integument of the Cephalopoda.

In the Chelonia, scales, when developed, are confined to the head and neck, the limbs and the tail, but in all of them, with the exception of the soft tortoises, both dorsal and ventral surfaces are covered by a system of large horny plates. A series of horny head-shields usually cover the dorsal surface of the head. Beneath the horny plates of the dorsal and ventral surfaces are the bony carapace and plastron, partly composed of dermal bones, but so intimately united with elements derived from the endoskeleton that the entire structure is best described in connection with the latter (p. 443).

In the Crocodilia, the dorsal surface is covered with longitudinal rows of sculptured horny plates, beneath which are bony dermal scutes of corresponding form. The ventral surface of the body is covered with scales like those of a lizard. The horny plates of the dorsal surface of the tail are elevated into a longitudinal crest.

A periodical *ecdysis* or casting and renewal of the outer layers of the horny epidermis takes place in all the Reptilia. Sometimes this occurs in a fragmentary manner; but in snakes and many lizards the whole comes away as a continuous slough.

The *vertebræ* are always fully ossified. Only in the geckos and Hatteria are the centra amphicœlous, with remnants of the notochord in the inter-central spaces. In most of the others the centra are procœlous, a ball-like convexity on the posterior surface of each centrum projecting into a cup-like concavity on the anterior face of the next.

The various regions of the spinal column are well marked in most of the lizards, in the Chelonia, and in the Crocodilia (Fig. 264). In the snakes and many of the snake-like lizards only two regions are distinguishable — pre-caudal and caudal. In the others there is a sacral region comprising two vertebræ, which have strong transverse processes for articulation with the ilia. The first and second vertebræ are always modified to form an atlas and axis. Ribs are developed in connection with all the vertebræ of the pre-sacral or precaudal region; in the caudal region they are usually replaced by inferior arches. In the flying lizards (*Draco*) a number of the ribs are greatly produced, and support a pair

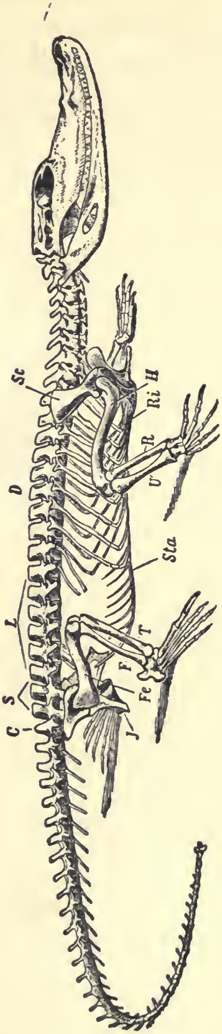

FIG. 264.—Skeleton of crocodile. *C*, caudal region; *D*, thoracic region of spinal column; *F*, fibula; *Fe*, femur; *H*, humerus; *I*, ischium; *L*, lumbar region; *R*, radius; *Ri*, ribs; *S*, sacrum; *Sc*, scapula; *Sta*, abdominal ribs; *T*, tibia; *U*, ulna. (From Zittel.)

of wide flaps of skin at the sides of the body, acting as wings or rather as parachutes. In Hatteria and Crocodilia (Fig. 264) each rib has connected with it posteriorly a flattened curved cartilage, the *uncinate*.

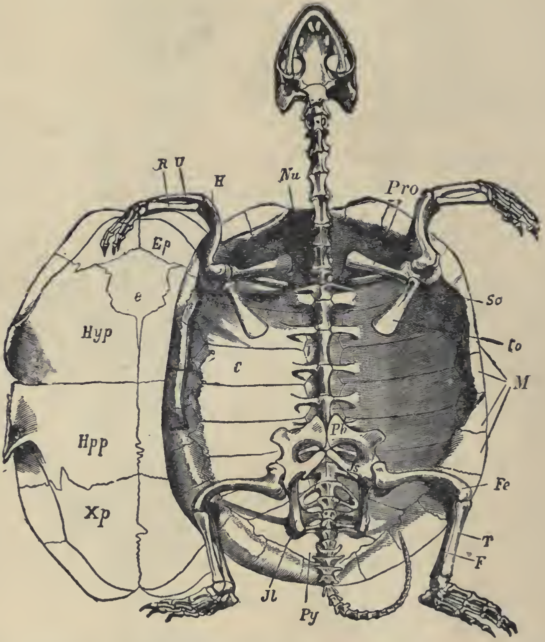

FIG. 265. — **Cistudo lutaria.** Skeleton seen from below; the plastron has been removed and is represented on one side. *C.* costal plate; *Co*, coracoid; *e*, entoplastron; *Ep*, epiplastron; *F*, fibula; *Fe*, femur; *H*, humerus; *Il*, ilium; *Is*, ischium; *M*, marginal plates; *Nu*, nuchal plate; *Pb*, pubis; *Pro*, pro-coracoid; *Py*, pygal plates; *R*, radius; *Sc*, scapula; *T*, tibia; *U*, ulna. (From Zittel.)

In the Chelonia (Fig. 265) the total number of vertebræ is always smaller than in the members of the other orders. The cervical and the caudal are the only regions in which the vertebræ are movable upon one another. The vertebræ of the trunk, usually ten in number, are immovably united together. Each of the neural spines, from the second to the ninth inclusively, is expanded into a flat plate, and the row of *neural plates* (Fig. 266, V), thus formed constitutes the median portion of the carapace. The ribs are likewise immovable; a short distance from its origin each passes into a large bony *costal plate* (C), and the series of costal plates uniting by their edges form a large part of the carapace on either side of the row of neural plates. The carapace is made up of the neural and costal plates supplemented by a row of *marginal* plates (Figs. 265 and 266, *M*) running along the edge, and *nuchal* (*Nu*) and *pygal* (*Py*) plates situated respectively in front of and behind the row of neural plates.

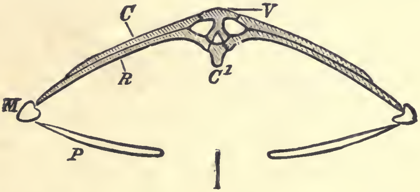

FIG. 266. — **Chelone midas.** Transverse section of skeleton. *C*, costal plate; C^1, centrum; *M*, marginal plate; *P*, lateral element of plastron; *R*, rib; *V*, expanded neural plate. (After Huxley.)

The bony elements of the plastron of the Chelonia are an anterior and median plate and six pairs of plates — the six pairs probably being of similar nature to the abdominal ribs of the Crocodilia.

The *sternum* in the Lacertilia is a plate of cartilage with a bifid posterior continuation. In the Ophidia and Chelonia it is absent. In the Crocodilia it is a broad plate with a posterior continuation or *hyposternum*, extending backwards as far as the pelvis.

A series of ossifications — the *abdominal ribs*, with a mesial *abdominal sternum* — lie in the wall of the abdomen in the Crocodilia (Fig. 264, *Sta*), and similar ossifications occur also in the monitors and in Hatteria. The elements of the plastron of the Chelonia are probably of a similar character.

In the *skull* ossification is much more complete than in the Amphibia, the primary chondrocranium persisting to a considerable extent only in some lizards and in Hatteria, and the number of bones is much greater.

The parasphenoid is reduced, and its place is taken by large basi-occipital, basi-sphenoid, and pre-sphenoid bones. The lower jaw articulates with the skull through the intermediation of a quadrate bone, which is movable in the lizards and snakes, fixed in Hatteria, the Chelonia, and Crocodilia.

A remarkable feature of the skull of the snakes (Fig. 267), is the free articulations of the bones of the jaws, permitting of the mouth being opened very wide so as to allow the passage of the relatively large animals which the snake swallows whole; this wide opening of the mouth is further aided by the two halves of the mandible not being firmly fixed together anteriorly, but merely connected together by means of elastic tissue, so that they are capable of being widely separated from one another.

In accordance with their purely aërial mode of respiration, the *visceral arches* are much more reduced in the Reptilia than in the Amphibia in general. The only well-developed post mandibular arch is the hyoid, and even this may undergo considerable reduction (Ophidia). The branchial arches, except in so far as they may contribute to the formation of the tracheal rings, are not represented in the adult, with the exception of most Chelonia, in which the first branchial arch persists.

In the lizard (Fig. 268) and crocodiles there is a cross-shaped membrane-bone, the *interclavicle* or *episternum* (*epist*), in relation to the pectoral arch and sternum. In the limbless lizards the pectoral arch may be absent or may be well developed; it is completely wanting in all snakes. In the pelvic arch the ischium is separated from the pubis by a wide space not developed in the Amphibia. Slight vestiges of hind-limbs occur in some pythons alone among the Ophidia.

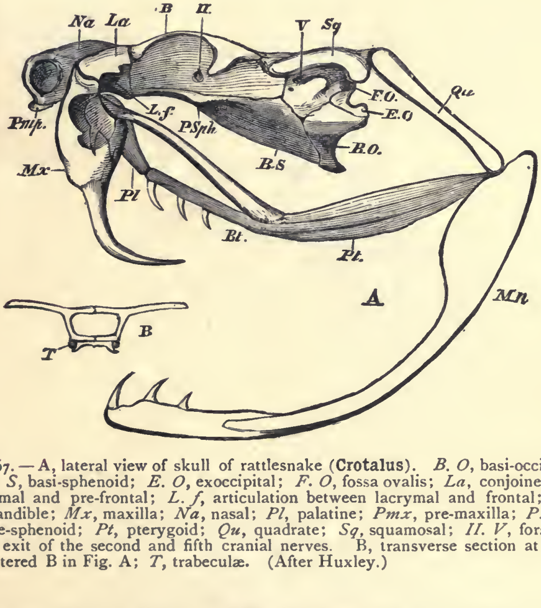

FIG. 267. — A, lateral view of skull of rattlesnake (**Crotalus**). *B. O*, basi-occipital; *B. S*, basi-sphenoid; *E. O*, exoccipital; *F. O*, fossa ovalis; *La*, conjoined lacrymal and pre-frontal; *L. f*, articulation between lacrymal and frontal; *Mn*, mandible; *Mx*, maxilla; *Na*, nasal; *Pl*, palatine; *Pmx*, pre-maxilla; *P. Sph*, pre-sphenoid; *Pt*, pterygoid; *Qu*, quadrate; *Sq*, squamosal; *II. V*, foramina of exit of the second and fifth cranial nerves. B, transverse section at point lettered B in Fig. A; *T*, trabeculæ. (After Huxley.)

In the lizards teeth are present in the pre-maxillæ, the maxillæ, the mandible, and usually the palatines. These are in most lizards small and simple, and uniform in shape and arrangement. A Mexican Lizard, *Heloderma*, which also occurs in Utah and Arizona, differs from all the rest in having teeth which are perforated for the ducts of poison-glands. In the snakes (Fig. 267) teeth are rarely developed on the pre-maxillæ, but are present on the maxillæ, palatines, pterygoids, and sometimes the transverse bones, as well as the dentary of the mandible. They may be of the same nature throughout, solid, elongated, sharp-pointed teeth, which are usually strongly recurved, so that they have the character of sharp hooks, their function being rather to hold the prey and prevent it slipping from the mouth while being swallowed than to masticate it. Non-venomous snakes possess teeth only of this character. In the venomous snakes, more or fewer of the maxillary teeth assume the character of poison-fangs. These are usually much larger than the ordinary teeth, and either grooved or perforated by a canal

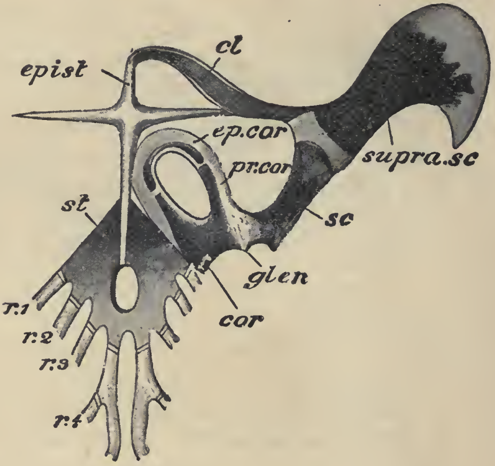

FIG. 268. — Pectoral arch and sternum of a lizard (**Lacerta agilis**). *cl*, clavicle; *cor*, coracoid; *ep. cor*, epicoracoid; *epist*, episternum; *glen*, glenoid cavity for head of humerus; *pr. cor*, pro-coracoid; *r. 1 — r. 4*, first to fourth sternal ribs; *sc*, scapula; *st*, sternum; *supra. sc*, supra-scapula. (After Hoffman.)

for the passage of the duct of the poison-gland. In the vipers there is a single large curved poison-fang with small reserve-fangs at its base, these being the only teeth borne by the maxilla, which is very short; in the venomous colubrine snakes the poison-fangs are either the most anterior or the most posterior of a considerable range of maxillary teeth. In the vipers the large poison-fang is capable, owing to the maxilla in which it is fixed being movable on a hinge-joint, of being rotated through a considerable angle, and moved from a nearly horizontal position, in which it lies along the roof of the mouth, embedded in folds of the mucous membrane, to a nearly vertical one when the snake opens his mouth to strike its prey.

In Hatteria there are pointed, triangular, laterally-compressed teeth, arranged in two parallel rows, one along the maxilla, the other along the palatine. The teeth of the lower jaw, which are of similar character, bite in between these two upper rows, all the rows becoming worn down in the adult in such a way as to form continuous ridges. Each pre-maxilla bears a prominent, chisel-shaped incisor, represented in the young animal by two pointed teeth. In the young Hatteria a tooth has been found on each vomer — a condition exceptional among reptiles.

In the Chelonia, teeth are entirely absent, the jaws being invested in a horny layer in such a way as to form a structure like a bird's beak.

The Crocodilia have numerous teeth which are confined to the pre-maxillæ, the maxillæ, and the dentary. They are large, conical, hollow teeth, devoid of roots, each lodged in its socket or alveolus, and each becoming replaced, when worn out, by a successor developed on its inner side.

In the *enteric canal* of the Reptiles the principal special features to be noticed are the muscular, gizzard-like stomach of the Crocodilia, the presence of a rudimentary cæcum at the junction of small and large intestines in most Lacertilia and in the Ophidia, and the presence of numerous large cornified papillæ in the œsophagus of the Turtles.

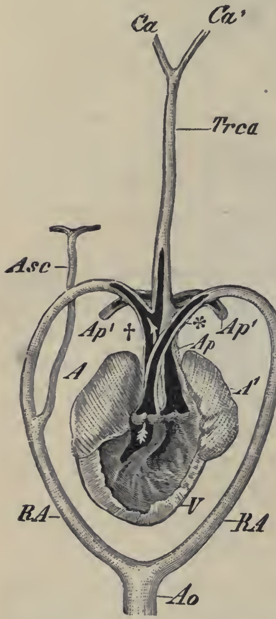

Fig. 269. — Heart of monitor (**Varanus**) dissected to show the cavity of the ventricle and the vessels leading out from it. *A. A'*, auricles; *Ao*, dorsal aorta; *Ap. Ap'*, pulmonary arteries; *Asc*, subclavian artery; *Ca. Ca'*, carotids; *RA. RA*, roots of dorsal aorta; *Trca*, innominate trunk; *V*, ventricle; †, right aortic arch; *, left aortic arch. (From Wiedersheim.)

The Reptiles have all an elongated *trachea*, the wall of which is supported by numerous cartilaginous rings. The anterior part of this is dilated to form the *larynx*, the wall of which is supported by certain special cartilages—the cricoid and the arytenoids. The trachea bifurcates posteriorly to form two bronchi, right and left, one passing to each lung.

The *lungs* of the Lacertilia and Ophidia are simple and sac-like, like those of the frog. In the Crocodilia and Chelonia they are of a more complex character, being divided internally by septa into a number of chambers.

In the *heart* (Fig. 269) the sinus venosus is always distinct, and is divided into two parts by a septum; its aperture of communication with the right auricle is guarded by valves. There are always two quite distinct auricles, as in the Amphibia, the right receiving the venous blood from the body, the left the oxygenated blood brought from the lungs by the pulmonary veins. But a vital point of difference between the heart of the reptile and that of the amphibian is that in the former the ventricle is always more or less completely divided into right and left portions. In all the Lacertilia, Ophidia, and Chelonia the ventricle is incompletely divided by a septum which does not entirely cut off the two portions of the cavity from one another. But in the Crocodilia the cavity is completely divided, so that we may speak of distinct right and left ventricles.

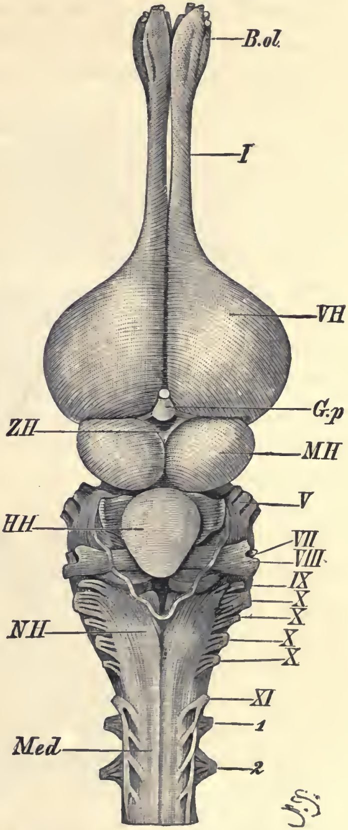

Fig. 270. — Brain of alligator, from above. *B. ol.*, olfactory bulb; *G. p*, epiphysis; *HH*, cerebellum; *Med*, spinal cord; *MH*, optic lobes; *NH*, medulla oblongata; *VH*, cerebral hemispheres; *I—XI*, cranial nerves; 1, 2, first and second spinal nerves. (After Wiedersheim.)

The *brain* of Reptiles is somewhat more highly organised than that of the Amphibia. The cerebral hemispheres are well developed in all. The midbrain consists usually of two closely approximated oval optic lobes. The cerebellum is always of small size, except in the Crocodilia (Fig. 270), in which it is comparatively highly developed, and consists of a median and two lateral lobes.

The *eyes* are relatively large, with a cartilaginous sclerotic in which a ring of bony plates is developed in some cases. Most reptiles have both upper and lower eyelids and nictitating membrane. The greater number of the geckos and all the snakes constitute exceptions, movable eyelids being absent in both these groups. In the chamæleons there is a single circular eyelid with a central aperture.

The middle ear is absent in the snakes, though a columella auris is present, embedded in muscular and fibrous tissue.

Developed in close relation to the epiphysis there is in many lizards (*Lacerta*, *Varanus*, *Anguis*, *Grammatophora*, and others) and in Hatteria, a remarkably eye-like organ — the *pineal eye* (Fig. 271), which is situated in a foramen of the cranial roof immediately under the integument, and covered over by a specially modified, transparent scale. Like the epiphysis itself, the pineal eye is developed as a hollow outgrowth of the roof of the diencephalon; the distal end of this becomes constricted off as a hollow sphere, while the remainder becomes converted into a nerve. The nerve degenerates before the animal reaches maturity, so that the organ would appear — though evidently, from its structure, an organ of sight — to have now entirely or nearly lost its function.

Though fertilisation is always internal, most Reptilia are oviparous, laying eggs clothed in a tough, parchment-like or calcified shell. These are usually deposited in holes and left to hatch by the heat of the sun. In the crocodiles they are deposited in a rough nest and guarded by the mother. In all cases development has only progressed to a very early stage when the deposition of the eggs takes place, and it is only after a more or less prolonged period of incubation that the young, fully formed in almost every respect, emerge from the shell and shift for themselves. Many lizards, however, and a few snakes are viviparous, the ova being developed in the interior of the oviduct, and the young reaching the exterior in the completely formed condition.

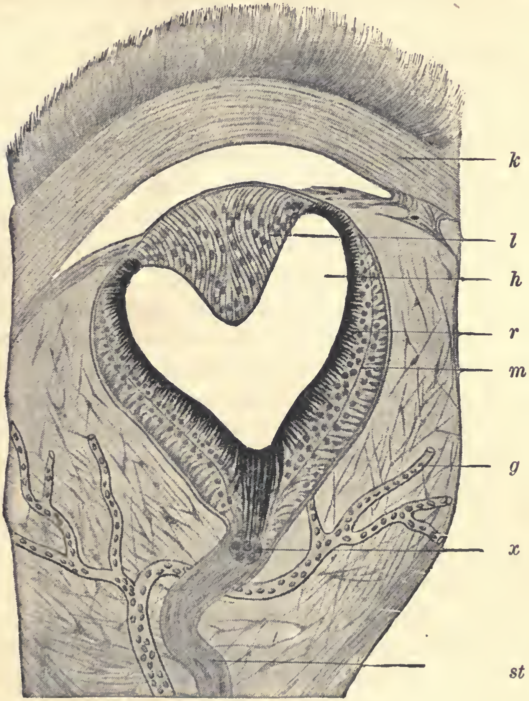

FIG. 271. — Section of the pineal eye of **Hatteria punctata.** *g*, blood-vessels; *h*, cavity of the eye filled with fluid; *k*, capsule of connective tissue; *l*, lens; *m*, molecular layer of the retina; *r*, retina; *st*, stalk of the pineal eye; *x*, cells in the stalk. (From Wiedersheim, after Baldwin Spencer.)

The lizards are for the most part terrestrial animals, usually extremely active in their movements and endowed with keen senses. The majority readily ascend trees, and many kinds are habitually arboreal ; but the chamæleons are the only members of the group which have special modifications of their structure in adaptation with an arboreal mode of life. The skinks and the amphisbænians are swift and skilful burrowers. The geckos are enabled by the aid of the sucker-like discs on the ends of their toes to run readily over vertical or overhanging smooth surfaces. A few lizards, on the other hand, live habitually in fresh water. The flying lizards (*Draco*) are arboreal, and make use of their wings — or, to speak more accurately, aëroplane or parachute (thin folds of skin supported by the greatly produced ribs) — to enable them to take short flights from branch to branch. *Chalmydosaurus* and certain other genera are exceptional in frequently running on the hind-feet, with the fore-feet entirely elevated from the ground. A tolerably high temperature is essential for the maintenance of the vital activities of lizards, low temperatures bringing on an inert condition, which usually passes, during the coldest part of the year, into a state of suspended animation or hibernation. The food of lizards is entirely of an animal nature. The smaller kinds prey on insects of all kinds, and on worms. Chamæleons, also, feed on insects, which they capture by darting out the extensile tongue covered with a viscid secretion. Other lizards supplement their insect diet, when opportunity offers, with small reptiles of various kinds, frogs and newts, small birds and their eggs, and small mammals, such as mice and the like. The larger kinds, such as the monitors and iguanas prey exclusively on other vertebrates ; some, on occasion, are carrion-feeders. Most lizards lay eggs enclosed in a tough calcified shell. These they simply bury in the earth, leaving them to be hatched by the heat of the sun. Some, however, are viviparous; in all cases the young are left to shift for themselves as soon as they are born.

Snakes are also usually extremely active and alert in their movements; and most are very intolerant of cold, undergoing a hibernation of greater or less duration during the winter season. Many live habitually on the surface of the ground — some kinds by preference in sandy places or among rocks, others among long herbage. Some (tree-snakes) live habitually among the branches of trees. Others (fresh-water snakes) inhabit fresh water; others (sea-snakes) live in the sea. The mode of locomotion of snakes on the ground is extremely characteristic, the reptile moving along by a series of horizontal undulations brought about by contractions of the muscles inserted into the ribs, any inequalities on the surface of the ground serving as fulcra against which the free posterior edges of the ventral shields (which are firmly connected with the ends of the ribs) are enabled to act. The burrowing blind-snakes and other families of small snakes feed on insects and worms. All the rest prey on vertebrates of various kinds — fishes, frogs, lizards, snakes, birds and their eggs, and mammals. The pythons and boas kill their prey by constriction, winding their body closely round it and drawing the coils tight till the victim is crushed or asphyxiated. Some other non-venomous snakes kill with bites of their numerous sharp teeth. The venomous snakes sometimes, when the prey is a small and weak animal such as a frog, swallow it alive: usually they first kill it with the venom of their poison-fangs.

When a venomous snake strikes, the poison is pressed out from the poison-gland by the contraction of the masseter

(Fig. 272, *Mc*), one of the muscles which raise the lower jaw: it is thus forced along the duct (*Gc*) to the aperture (*za*), and injected into the wound made by the fang. The effect is to produce acute pain with increasing lethargy and weakness, and in the case of the venom of some kinds of snakes, paralysis. According to the relative amount of the poison injected and the degree of its virulence (which differs not only in different kinds of snakes, but in the same snake under different conditions) the symptoms may result in death, or the bitten animal may recover. The poison is a clear, slightly straw-coloured or greenish liquid; it preserves its venomous properties for an indefinite period, even if completely desiccated. The poisonous principles are certain proteids not to be distinguished chemically from other proteids which have no such poisonous properties. Immunity against the effects of the poison, and relief of the symptoms after a bite has been inflicted, have been found to be conferred by injections of the serum of animals which have

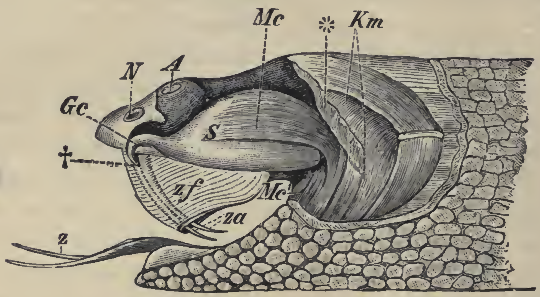

FIG. 272.—Poison apparatus of rattlesnake. *A*, eye; *Gc*, poison-duct entering the poison-fang at †; *Km*, muscles of mastication partly cut through at *; *Mc*, masseter or constrictor muscle; *Mc'*, continuation of the constrictor muscle to the lower jaw; *N*, nasal opening; *S*, fibrous poison-sac; *z*, tongue; *za*, opening of the poison-duct; *zf*, pouch of mucous membrane enclosing the poison-fangs. (From Wiedersheim.)

been treated with injections of increasing doses of the poison.

The majority of snakes are viviparous. Some, however, lay eggs, which, nearly always, like those of the oviparous lizards, are left to be hatched by the heat of the sun, some of the Pythons being exceptional in incubating them among the folds of the body.

Hatteria lives in burrows in company with mutton-birds (Puffinus), and feeds on insects and small birds. It lays eggs enclosed in a tough parchment-like shell. The eggs are laid in November, and the embryos pass the winter in a state of hibernation unknown to any other vertebrate embryo, not emerging from the egg until nearly thirteen months have elapsed (Dendy).

Of the Chelonia some (land-tortoises) are terrestrial; others (fresh-water tortoises) inhabit streams and ponds, while the sea-turtles and luths, or leather-backed turtles, inhabit the sea. Even among reptiles they are remarkable for their tenacity of life, and will live for a long time after severe mutilations, even after the removal of the brain; but they readily succumb to the effects of cold. Like most other reptiles, the land and fresh-water tortoises living in colder regions hibernate in the winter; in warmer latitudes they sometimes pass through a similar period of quiescence in the dry season. The food of the green turtles is exclusively vegetable; some of the land tortoises are also exclusively vegetable feeders; other Chelonia either live on plant food, together with worms, insects, and the like, or are completely carnivorous. All are oviparous, the number of eggs laid being usually very great (as many as 240 in the sea-turtles); these they lay in a burrow carefully prepared in the earth, or, in the case of the sea-turtles, in the sand of the sea-shore, in a round hole about fifteen or twenty inches deep and ten inches in diameter, and having covered them over, leave them to hatch.

The crocodiles and alligators, the largest of living reptiles, are in the main aquatic in their habits, inhabiting rivers, and, in the case of some species, estuaries. Endowed with great muscular power, these reptiles are able, by the movements of the powerful tail and the webbed hind-feet, to dart through the water with lightning-like rapidity. By lying in wait motionless, sometimes completely submerged with the exception of the extremity of the snout bearing the nostrils, they are often able by the suddenness and swiftness of their onset to seize the most watchful and timid animals. In the majority of cases the greater part, and in some the whole, of their food consists of fishes; but all the larger and more powerful kinds prey also on birds and mammals of all kinds, which they seize unawares when they come down to drink or attempt to cross the stream. On land their movements are comparatively slow and awkward, and they are correspondingly more timid and helpless.

The Crocodilia are all oviparous, and the eggs, as large in some species as those of a goose, are brought forth in great numbers (sometimes 100 or more), and either buried in the sand or deposited in rough nests.

CLASS V. AVES

In many respects birds are the most highly specialised of Craniata. As a class they are adapted for aerial life, and almost every part of their organisation is modified in accordance with the unusual environment. The non-conducting covering of feathers; the modification of the fore-limbs as wings, of the sternum and shoulder-girdle to serve as origins of the wing-muscles, and of the pelvic girdle and hind-limbs to enable them to support the entire weight of the body on land; the perfection of the respiratory system, producing a higher temperature than in any other animals,—all these peculiarities are of the nature of adaptations to flight.

The common or domestic pigeon is known under many varieties which differ from one another in size, proportions, coloration, details in the arrangements of the feathers, and in many points of internal anatomy.

The following description refers especially to the common dovecot pigeon.

In the entire bird (Fig. 273) the plump trunk appears to be continued insensibly into the small, mobile head, with its rounded brain-case and prominent *beak* formed of the upper and lower jaws covered by horny sheaths. The head, neck, and trunk are invested in a close covering of *feathers*, all directed backwards and overlapping one another. Posteriorly the trunk gives origin to a number of outstanding feathers which constitute what is ordinarily called the tail. From the anterior region of the trunk spring the *wings*, also covered with feathers, and, in the position of rest, folded against the sides of the body. The legs spring from the hinder end of the trunk, but, owing to the thick covering of feathers, only the feet are to be seen in the living bird, each covered with *scales* and terminating in four digits (*dg 1′* — *dg 4′*), three directed forwards and one backwards.

In order to make a fair comparison of the outer form with that of other craniate types, it is necessary to remove the feathers. When this is done the bird is seen to have a long, cylindrical, and very mobile neck, sharply separated both from head and trunk. The true tail is a short, conical projection of the trunk, known as the *uropygium*, and giving origin to the group of large feathers (*rct*) to which the word "tail" is usually applied. On the dorsal surface of the uropygium is a papilla bearing on its summit the opening of

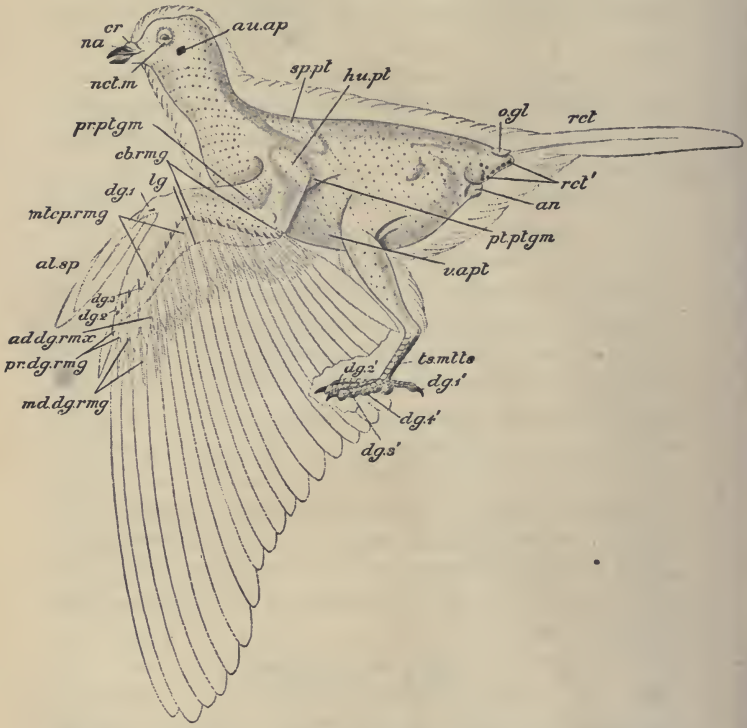
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Fig. 273. — **Columba livia.** The entire animal from the left side with most of the feathers removed. *ad. dg. rmx*, ad-digital remex; *al. sp*, ala spuria; *an*, anus: *au. ap*, auditory aperture; *cb. rmg*, cubital remiges; *cr*, cere; *dg. 1, 2, 3*, digits of manus; *dg. 1′, 2′, 3′, 4′*, digits of pes; *hu pt*, humeral pteryla; *lg*, ligament of remiges; *md. dg. rmg*, mid-digital remiges; *na*, nostril; *nct. m*, nictitating membrane; *o. gl*, oil gland; *pr. dg. rmg*, pre-digital remiges; *pr. ptgm*, pre-patagium; *pt. ptgm*, post-patagium; *rct*, mesial rectrix of right side; *rct′*, sacs of left rectrices; *sp. pt*, spinal pteryla; *ts. mtts*, tarso-metatarsus; *v. apt*, ventral apterium, or featherless space.

a large gland, the *oil-gland* (*o.gl*), used for lubricating or "preening" the feathers.

The wings show the three typical divisions of the fore-limb, upper arm, fore-arm, and hand, but the parts of the hand are closely bound together by skin, and only three imperfectly marked digits, the second (*dg 2*) much larger than the first (*dg 1*) and third (*dg 3*), can be distinguished. In the position of rest the three divisions of the wing are bent upon one another in the form of a Z: during flight the entire wing is straightened out at right angles to the trunk. In the hind-limb the short thigh is closely bound to the trunk: the foot is clearly divisible into a proximal portion, the *tarso-metatarsus* (*ts. mtts*) and four digits, of which one, the hallux (*dg 1'*), is directed backwards, the others, the second, third, and fourth of the typical foot, forwards.

The mouth is terminal and is guarded by the elongated upper and lower beaks; it has, therefore, a very wide gap. On each side of the base of the upper beak is a swollen area of soft skin, the *cere* (*cr*) surrounding the *nostril* (*na*), which has thus a remarkably backward position. The *eyes* are very large, and each is guarded by an upper and a lower eyelid and a transparent nictitating membrane (*nct. m*). A short distance behind the eye is the *auditory aperture* (*au. ap*), concealed by feathers in the entire bird, and leading into a short external auditory meatus, closed below by the tympanic membrane. The *anus* or cloacal aperture (*an*), is a large, transversely elongated aperture placed on the ventral surface at the junction of the uropygium with the trunk.

The exoskeleton is purely epidermal, like that of the lizard, which it also resembles in consisting partly of horny *scales*. These cover the tarso-metatarsus and the digits of the foot, and are quite reptilian in appearance and structure.

Each digit of the foot is terminated by a claw which is also a horny product of the epidermis, and the beaks are of the same nature. The rest of the body, however, is covered by *feathers*, a unique type of epidermal product found nowhere outside the present class.

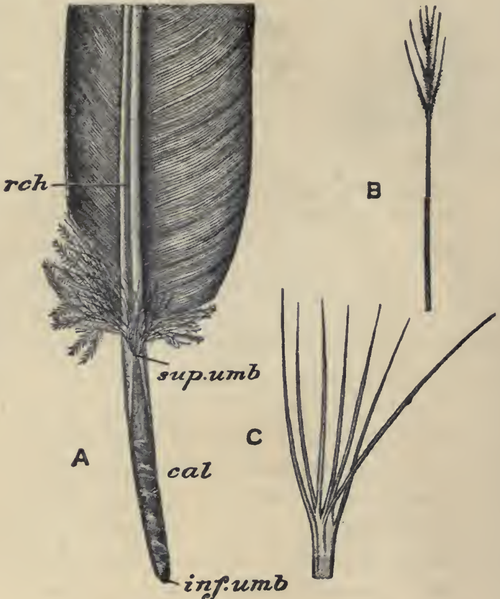

FIG. 274.—**Columba livia.** A, proximal portion of a remex. *cal*, calamus; *inf. umb*, inferior umbilicus; *rch*, rachis; *sup. umb*, superior umbilicus. B, filoplume. C, nestling-down. (C, from Bronn's *Thierreich*.)

A feather (Fig. 274) is an elongated structure consisting of a hollow stalk, the *calamus* or quill (*cal*), and an expanded distal portion, the *vexillum* or vane. At the proximal end of the quill is a small aperture, the *inferior umbilicus* (*inf. umb*), into which fits, in the entire bird, a small conical prolongation of the skin, the *feather papilla*. A second extremely minute aperture, the *superior umbilicus* (*sup. umb*), occurs at the junction of the quill with the vane on the inner or ventral face of the feather, *i.e.*, the face adjacent to the body.

The vane has a longitudinal axis or *rachis* (*rch*) continuous proximally with the quill, but differing from the latter in being solid. To each side of the rachis is attached a kind of membrane forming the expanded part of the feather and composed of *barbs*, delicate thread-like structures which extend obliquely outwards from the rachis. In an uninjured feather the barbs are closely connected so as to form a continuous sheet, but a moderate amount of force separates them from one another, and it can readily be made out with the aid of a magnifying glass that they are bound together by extremely delicate oblique filaments, the *barbules*, having the same general relation to the barbs as the barbs themselves to the rachis.

Adjacent barbules interlock by means of a system of minute hooklets and flanges, and in this way the parts of the feather are so bound together that the entire structure offers great resistance to the air.

Among the *contour feathers* which form the main covering of the bird and have the structure just described, are found *filoplumes* (Fig. 274, B), delicate hair-like feathers having a long axis and a few barbs, devoid of locking apparatus, at the distal end. Nestling pigeons are covered with a temporary investment of *down feathers* (C), in which also there is no interlocking of the barbs: when these first appear each is covered by a horny sheath like a glove finger.

Feathers, like scales, arise in the embryo from papillæ of the skin formed of derm with an epidermal covering. The papilla becomes sunk in a sac, the *feather-follicle*, from which it subsequently protrudes as an elongated *feather-germ*, its vascular dermal interior being the *feather-pulp*. The horny substance of the feather is formed from the epidermis of the feather-germ.

The feathers do not spring uniformly from the whole surface of the body, but from certain defined areas (Fig. 275), the *feather tracts* or *pterylæ* (*sp. pt*, *hu. pt*, etc.), separated from one another by featherless spaces or *apteria* (*v. apt*, etc.), from which only a few filoplumes grow.

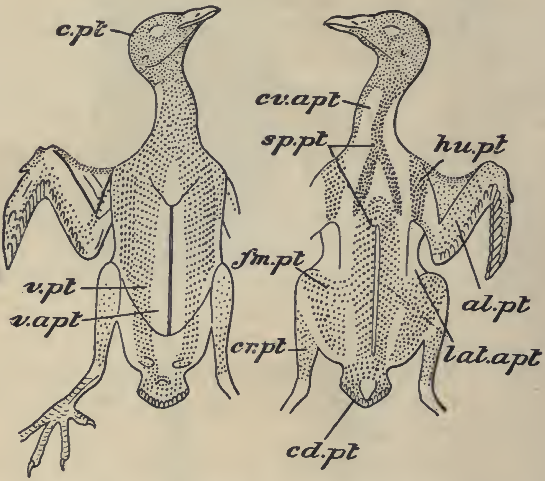

FIG. 275.—Pterylosis of **Columba livia**. A, ventral; B, dorsal. *al. pt*, alar pteryla or wing-tract; *c. pt*, cephalic pteryla or head-tract; *cd. pt*, caudal pteryla or tail-tract; *cr. pt*, crural pteryla; *cr. apt*, cervical apterium or neck-space; *fm. pt*, femoral pteryla; *hu. pt*, humeral pteryla; *lat. apt*, lateral apterium; *sp. pt*, spinal pteryla; *v. apt*, ventral apterium; *v. pt*, ventral pteryla. (After Nitsch.)

In the wings and tail certain special arrangements of the feathers are to be distinguished. When the wing is stretched out at right angles to the trunk, twenty-three large feathers (Fig. 273) are seen to spring from its hinder or post-axial border: these are the *remiges* or wing-quills. Twelve of them are connected with the ulna and are called *cubitals* or *secondaries* (*cb. rmg*). The rest are known as *primaries*. In the tail there are twelve long *rectrices* (*rct*) or tail-quills springing in a semicircle from the uropygium. The whole feather-arrangement is known as the *pterylosis*.

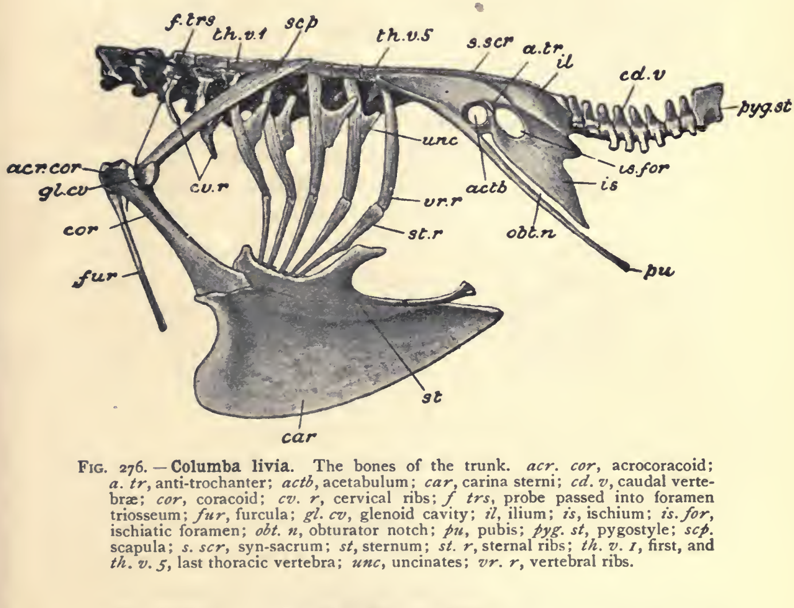

FIG. 276. — **Columba livia.** The bones of the trunk. *acr. cor*, acrocoracoid; *a. tr*, anti-trochanter; *actb*, acetabulum; *car*, carina sterni; *cd. v*, caudal vertebræ; *cor*, coracoid; *cv. r*, cervical ribs; *f trs*, probe passed into foramen triosseum; *fur*, furcula; *gl. cv*, glenoid cavity; *il*, ilium; *is*, ischium; *is. for*, ischiatic foramen; *obt. n*, obturator notch; *pu*, pubis; *pyg. st*, pygostyle; *scp*. scapula; *s. scr*, syn-sacrum; *st*, sternum; *st. r*, sternal ribs; *th. v. 1*, first, and *th. v. 5*, last thoracic vertebra; *unc*, uncinates; *vr. r*, vertebral ribs.

The *vertebral column* is distinguished from that of most other Craniata by the great length and extreme mobility of the neck, the rigidity of the trunk region, and the shortness of the tail. There are fourteen cervical vertebræ, the last two of which have double-headed ribs (Fig. 276, *cv. r*) each having its proximal end divisible into the *head* proper articulating with the centrum of the vertebra, and a *tubercle* with the transverse process: their distal ends are free, not uniting with the sternum. In the third to the twelfth there are vestigial ribs (Fig. 277, *rb*), each having its head fused with the centrum, and its tubercle with the transverse process. The whole rib thus has the appearance of a short, backwardly directed transverse process perforated at its base.

The centra of the cervical vertebræ differ from those of all other Vertebrata in having saddle-shaped surfaces, the anterior face (Fig. 277, A) being concave from side to side and convex from above downwards. This peculiar form of vertebra is distinguished as *heterocœlous*.

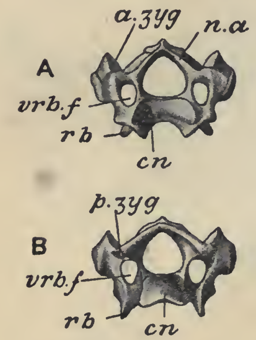

FIG. 277.—**Columba livia.** Cervical vertebra; A, anterior; B, posterior face. *a. zyg*, anterior zygapophysis; *cn*, centrum; *n. a*, neural arch; *p. zyg*, posterior zygapophysis; *rb*, rib; *vrb. f*, vertebrarterial foramen.

The first two vertebræ, the *atlas* and *axis*, are specially modified. The atlas is a ring-like bone with an articulation on its anterior surface for the single occipital condyle of the skull. The axis has projecting forwards from its centrum, a peg-like process, the *odontoid* process, which lies in the lower part of the ring of the atlas.

Between the last cervical vertebra and the pelvic region come four thoracic vertebræ (Fig. 276), the first three united into a single mass, the fourth free. They all bear ribs, each consisting of a vertebral (*vr. r*) and a sternal (*st. r*) portion, and articulating with the vertebra by a double head. Springing from the posterior edge of the vertebral rib is an *uncinate* (Fig. 276, *unc*), resembling that of Hatteria and the crocodile, but formed of bone and ankylosed with the rib.

Following upon the fourth thoracic are about twelve vertebræ all fused into a single mass (Fig. 276, *s. scr*), and giving attachment laterally to the immense pelvic girdle. The whole of this group of vertebræ has, therefore, the function of a sacrum, differing from that of a reptile in the large number of vertebræ composing it. The first of them bears a pair of free ribs, and is, therefore, the fifth or last thoracic (*th. v. 5*). The next five or six have no free ribs, and may be looked upon as lumbar (Fig. 278, l^1—s^3). Next come two sacral vertebræ (c^1) homologous with those of the lizard. The remaining five vertebræ of the pelvic region are caudal. Thus the mass of vertebræ supporting the pelvic girdle in the pigeon is a compound sacrum, or *syn-sacrum*, formed by the fusion of the posterior thoracic, all the lumbar and sacral, and the anterior caudal vertebræ.

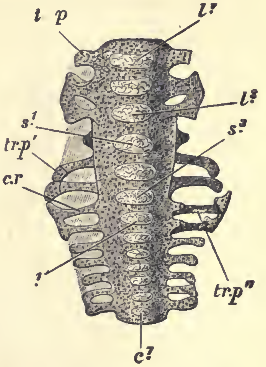

FIG. 278.—**Columba livia.** Sacrum of a nestling (about fourteen days old), ventral aspect. c^1, centrum of first sacral vertebra; c^1, centrum of fifth caudal; *c. r*, first sacral rib; l^1, centrum of first lumbar; l^3, of third lumbar; s^1, of fourth lumbar; s^3, of sixth lumbar; *tr. p*, transverse process of first lumbar; *tr. p'*, of fifth lumbar; *tr p''*, of first sacral. (From Parker's *Zootomy*.)

The syn-sacrum is followed by six free caudals and the vertebral column ends posteriorly in an upturned, compressed bone, the *pygostyle* or ploughshare-bone (Fig. 276, *pyg. st*), formed by the fusion of four or more of the hindermost caudal vertebræ.

The *sternum* (Fig. 276, *st*) is one of the most characteristic parts of the bird's skeleton. It is a broad plate of bone produced ventrally, in the sagittal plane, into a deep keel or *carina sterni* (*car*), formed, in the young bird, from a separate centre of ossification. The posterior border of the sternum presents two pairs of notches, covered, in the recent state,

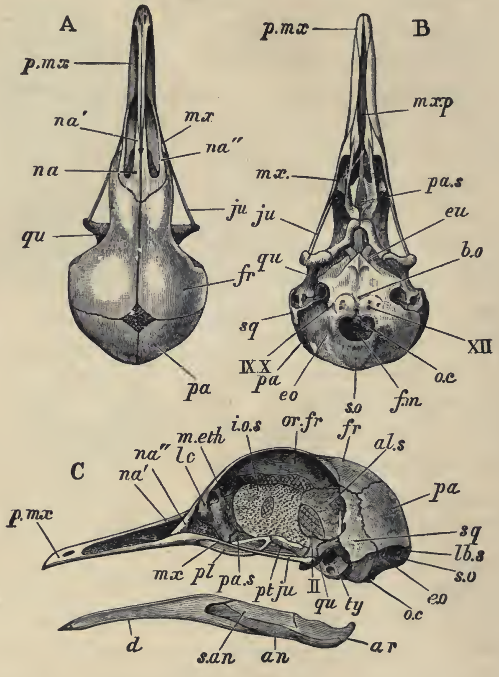
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FIG. 279.—**Columba livia.** Skull of young specimen. A, dorsal; B, ventral; C, left side. *al. s*, alisphenoid; *an*, angular; *ar*, articular; *b o*, basi-occipital; *d*, dentary; *e. o*, ex-occipital; *eu*, aperture of Eustachian tube; *f. m*, foramen magnum; *fr*, frontal; *i. o. s*, inter-orbital septum; *ju*, jugal; *lc*, lachrymal; *lb. s*, lambdoidal suture; *m. eth*, mesethmoid; *mx*, maxilla; *mx. p*, maxillo-palatine process; *na*, *na'*, *na''*, nasal; *o. c*, occipital condyle; *or. fr*, orbital plate of frontal; *pa*, parietal; *pa. s*, parasphenoid (rostrum); *pl*, palatine; *p. mx*, pre-maxilla; *pt*, pterygoid; *qu*, quadrate; *s. an*, supra-angular; *s. o*, supra-occipital: *sq*, squamosal; *ty*, tympanic cavity; II.—XII, foramina for cerebral nerves. (From Parker's *Zootomy*.)

by ligament; its anterior edge bears a pair of deep grooves for the articulation of the coracoids.

The *skull* (Fig. 279) is distinguished at once by its rounded brain-case, immense orbits, and long pointed beak. The foramen magnum (*f. m*) looks downwards as well as backwards, so as to be visible in a ventral view, and on its anterior margin is a single, small, rounded, occipital condyle (*o. c*). Most of the bones, both of the cranial and facial regions, are firmly ankylosed in the adult, and can be made out only in the young bird.

The premaxillæ (Fig. 279, *p. mx*) are united into a large triradiate bone which forms practically the whole of the upper beak. The maxillæ (Fig. 279, *mx*), on the other hand, are small, and have their anterior ends produced inwards into spongy *maxillo-palatine processes* (Fig. 279, *mx.p*). The slender posterior end of the maxilla is continued backwards by an equally slender jugal (*ju*) and quadrato-jugal to the quadrate. The latter (Fig. 279, *qu*) is a stout three-rayed bone articulating by two facets with the roof of the tympanic cavity, and presenting below a *condyle* for articulation with the mandible: the *mandible* of the young bird consists of a cartilage bone, the articular (Fig. 279, *ar*), and four membrane bones, which all coalesce in the

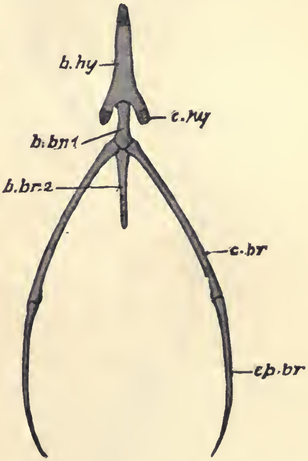

FIG. 280.—**Columbia livia.** Hyoid apparatus. The cartilaginous parts are dotted. *b. br. 1*, basi-branchials; *b hy*, basi-hyal; *c. br*, cerato-branchial; *c. hy*, hyoid cornu; *ep. br*, epi-branchial.

adult. The *hyoid apparatus* (Fig. 280), is of characteristic form, having an arrow-shaped body (*b. hy*) with a short pair of anterior cornua (*c. hy*) derived from the hyoid arch, and a long pair of posterior cornua (*c. br.*, *ep. br*) from the first branchial. The *columella* is a rod-shaped bone ankylosed to the stapes, and bearing at its outer end a three-rayed cartilage or *extra-columella* fixed to the tympanic membrane.

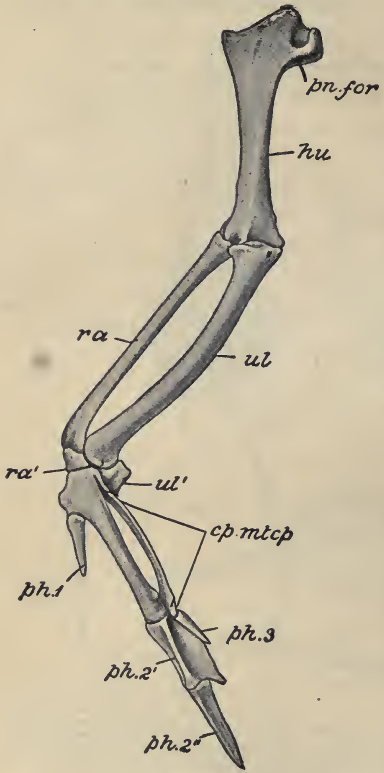

FIG. 281.—**Columba livia.** Skeleton of the left wing. *cp. mtcp*, carpo-metacarpus; *hu*, humerus; *ph.1*, phalanx of first digit; *ph.2'*, *ph.2''*, phalanges of second digit; *ph.3*, phalanx of third digit; *pn. for*, pneumatic foramen; *ra*, radius; *ra'*, radiale; *ul*, ulna; *ul'*, ulnare.

The *shoulder-girdle* (Fig. 276) is quite unlike that of other Craniates. There is a pair of stout, pillar-like *coracoids* (*cor*) articulating with deep facets on the anterior border of the sternum and directed upwards, forwards, and outwards. The dorsal end of each is produced into an *acrocoracoid process* (*acr. cor*), and below this, to the posterior aspect of the bone, is attached by ligament a sabre-shaped *scapula* (*scp*) which extends backwards over the ribs, and includes, with the coracoid, an acute angle, the *coraco-scapular angle*. The glenoid cavity (*gl. cv*) is formed in equal proportion by the two bones; internal to it the scapula is produced into an *acromion process*. In front of the coracoids is a slender V-shaped bone, the *furcula* (*fur*) or "merrythought," the apex of which nearly reaches the sternum, while each of its extremities is attached by ligament to the acromion and acro-coracoid processes of the corresponding side in such a way that a large aperture, the *foramen triosseum* (*f. trs*) is left between the three bones of the shoulder-girdle. The furcula is a membrane bone and represents fused clavicles and inter-clavicle.

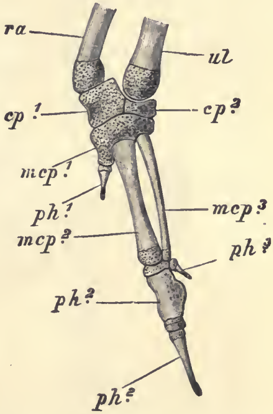

FIG. 282. — **Columba livia.** Left manus of a nestling. The cartilaginous parts are dotted. *cp. 1*, radiale; *cp. 2*, ulnare; *mcp. 1, 2, 3*, metacarpals; *ph. 1*, phalanx of first digit; *ph. 2, ph. 2'*, phalanges of second digit; *ph. 3*, phalanx of third digit; *ra*, radius; *ul*, ulna. (From Parker's *Zootomy*.)

Equally characteristic is the skeleton of the fore-limb. The *humerus* (Fig. 281, *hu*) is a large, strong bone, with a greatly expanded head and a prominent ridge for the insertion of the pectoral muscle. The *radius* (*ra*) is slender and nearly straight, the *ulna* stouter and gently curved. There are two large free carpals, a *radiale* (*ra'*) and an *ulnare* (*ul'*), and articulating with these is a bone called the *carpo-metacarpus* (*cp. mtcp*), consisting of two rods, that on the preaxial side strong and nearly straight, that on the postaxial side slender and curved, fused with one another at both their proximal and distal ends; the proximal end is produced pre-axially, into an outstanding step-like process.

The study of its development shows that this bone is formed by the union of the distal carpals with three metacarpals (Fig. 282), the second and third of which are the two rod-like portions of the bone, the first, the step-like projection. Articulating with the first metacarpal is a single pointed phalanx (*ph. 1*); the second metacarpal bears two phalanges, the proximal one (*ph. 2'*) produced postaxially into a flange, the distal one (*ph. 2''*) pointed; the third metacarpal bears a single pointed phalanx (*ph. 3*).

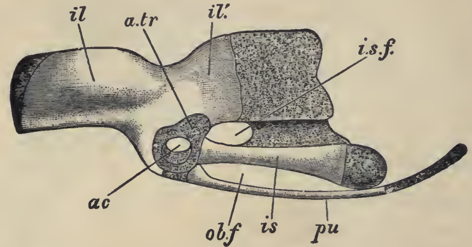

Fig. 283. — **Columba livia.** Left innominate of a nestling. The cartilage is dotted. *ac*, acetabulum; *a. tr*, anti-trochanter; *il*, pre-acetabular; and *il'*, post-acetabular portion of ilium; *is*, ischium; *i. s. f*, ischiatic foramen; *ob. f*, obturator notch; *pu*, pubis. (From Parker's *Zootomy*.)

The *pelvic girdle* (Fig. 283). The *ilium* (*il*) is an immense bone, attached by fibrous union with the whole of the syn-sacrum and becoming ankylosed with it in the adult. As usual it furnishes the dorsal portion of the acetabulum. The ventral portion of the acetabulum is furnished in about equal proportions by the pubis and ischium (Fig. 283): it is not completely closed by bone, but is perforated by an aperture covered by membrane in the recent state. Both pubis and ischium are directed sharply backwards from their dorsal or acetabular ends, and lie nearly parallel. Neither ischium nor pubis unites ventrally with its fellow to form a symphysis.

In the hind-limb the *femur* (Fig. 284, *fe*) is a comparatively short bone. Its proximal extremity bears a prominent *trochanter* (*tr*) and a rounded *head* (*hd*). Its distant end is produced into pulley-like *condyles*. Articulating with the femur is a very long bone, the *tibio-tarsus* (*ti. ts*); its distal end is pulley-like, not concave like the corresponding extremity of the tibia of other Amniota. The study of its development shows that the pulley-like distal end of the bone (Fig. 285, *tl*^{1}) consists of the proximal tarsals, — astragalus and calcaneum, — which at an early period unite with the tibia and give rise to the compound shank-bone of the adult. The *fibula* (Fig. 284, *fi*) is very small, much shorter than the tibia, and tapers to a point at its distal end.

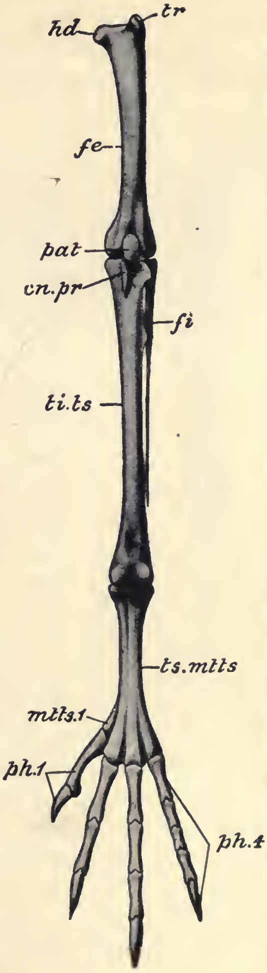

FIG. 284.—**Columba livia.** Bones of the left hind-limb. *cn. pr*, cnemial process; *fe*, femur; *fi*, fibula; *hd*, head; *mtts. 1*, first metatarsal; *pat*, patella; *ph. 1*, phalanx of first digit; *ph. 4*, phalanx of fourth digit; *ti. ts*, tibio-tarsus; *ts. mtts*, tarso-metatarsus; *tr*, trochanter.

Following the tibio-tarsus is an elongated bone, the *tarso-metatarsus* (*ts. mtts*), presenting at its proximal end a concave surface for the tibio-tarsus, and at its distal end three distinct pulleys for the articulation of the three forwardly directed toes. In the young bird the proximal end of this bone is a separate cartilage (Fig. 285, *tl*[2]), representing the distal tarsals, and followed by three distinct metatarsals, belonging respectively to the second, third, and fourth digits. To the inner or preaxial side of the tarso-metatarsus, near its distal end, is attached by fibrous tissue a small irregular bone, the first metatarsal (*mtts. 1*). The backwardly directed hallux has two phalanges, the second or inner toe three, the third or middle toe four, and the fourth or outer toe five. In all four digits the distal or ungual phalanx is pointed and curved, and serves for the support of the horny claw.

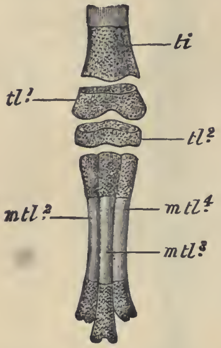

FIG. 285. — **Columba livia.** Part of left foot of an unhatched embryo (magnified). The cartilage is dotted. *mtl. 2*, second; *mtl. 3*, third; and *mtl.* 4, fourth metatarsal; *ti*, tibia; *tl. 1*, proximal tarsal cartilage; *tl. 2*, distal tarsal cartilage. (From Parker's *Zootomy*.)

A further peculiarity is the fact that the larger proportion of the bones contain no marrow, but are filled during life with air, and are therefore said to be pneumatic. The cavities of the various bones open externally in the dried skeleton by apertures called *pneumatic foramina* (Fig. 281, *pn. for*), by which, in the entire bird, they communicate with the air-sacs (*vide infra*).

As might naturally be expected, the *muscles* of the fore-limb are greatly modified. The powerful downstroke of the wing, by which the bird rises into and propels itself through the air, is performed by the *pectoralis* (Fig. 286, *pct*), an immense muscle having about one-fifth the total weight of the body; it arises from the whole of the keel of the sternum (*car. st*), from the posterior part of the body of that bone (*cp. st*), and from the clavicle (*cl*), filling nearly the whole of the wedge-shaped space between the body and the keel of the sternum, and forming what is commonly called the "breast" of the bird. Its fibres converge to their insertion (*pct''*) into the ventral aspect of the humerus

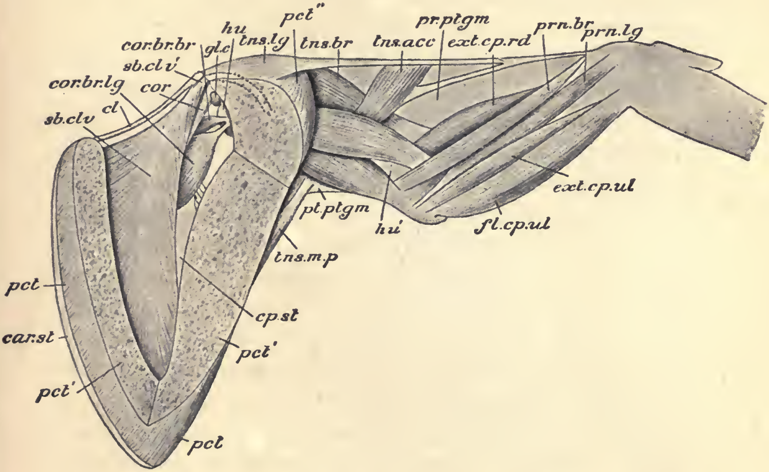
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FIG. 286. — **Columba livia.** The principal muscles of the left wing; the greater part of the pectoralis (*pct*) is removed. *car. st*, carina sterni; *cl*, furcula; *cor*, coracoid; *cor. br. br*, coraco-brachialis brevis; *cor. br. lg*, coraco-brachialis longus; *cp. st*, corpus sterni; *ext. cp. rd*, extensor carpi radialis; *ext. cp. ul*, extensor carpi ulnaris; *fl. cp. ul*, flexor carpi ulnaris; *gl. c*, glenoid cavity; *hu*, head of humerus; *hu'*, its distal end; *pct*, pectoralis; *pct'*, its cut edge; *pct''*, its insertion; *prn. br*, pronator brevis; *prn. lg*, pronator longus; *pr. ptgm*, prepatagium; *pt. ptgm*, post-patagium; *sb clv*, sub-clavius; *sb. clv'*, its tendon of insertion passing through the foramen triosseum, and dotted as it goes to the humerus; *tns. acc*, tensor accessorius; *tns. br*, tensor brevis; *tns. lg*, tensor longus; *tns. m. p*, tensor membranæ posterioris alæ.

(*hu*, *hu'*), which it depresses. The elevation of the wing is performed, not, as might be expected, by a dorsally placed muscle, but by the *sub-clavius* (*sb. clv*), arising from the anterior part of the body of the sternum, dorsal to the pectoralis, and sending its tendon (*sb. clv'*) through the foramen triosseum to be inserted into the dorsal aspect of the humerus. In virtue of this arrangement, the end of the foramen acting like a pulley, the direction of action of the muscle is changed, the backward pull of the tendon raising the humerus.

Digestive Organs. — The *mouth* (Fig. 287) is bounded above and below by the horny beaks, and there is no trace of teeth. The *tongue* (*tng*) is large and pointed at the tip. The pharynx leads into a wide and distensible *gullet* (*gul*), which soon dilates into an immense reservoir or *crop* (*crp*) situated at the base of the neck, between the skin and the muscles and immediately in front of the sternum. In this cavity the food, consisting of grain, undergoes a process of maceration before being passed into the stomach. From the crop the gullet is continued backwards into the *stomach*, which consists of two parts, the *proventriculus* (*prvn*) and the *gizzard* (*giz*). The proventriculus appears externally like a slight dilatation of the gullet, but its mucous membrane is very thick and contains numerous gastric glands so large as to be visible to the naked eye. The gizzard has the shape of a biconvex lens; its walls are very thick and its lumen small. The thickening is due mainly to the immense development of the muscles which radiate from two tendons, one on each of the convex surfaces. The epithelial lining of the gizzard is very thick and horny, and of a yellow or green colour: its cavity always contains small stones, which are swallowed by the bird to aid the gizzard in grinding up the food.

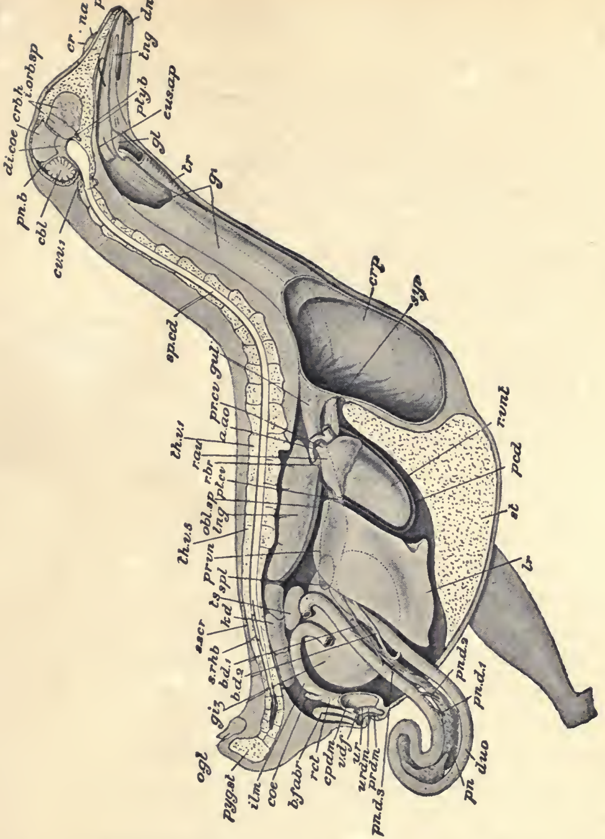
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FIG. 287. — **Columba livia.** Dissection from the right side. The body-wall, with the vertebral column, sternum, brain, etc., are in sagittal section; portions of the gullet and crop are cut away and the cloaca is opened; nearly the whole of the ilium is removed, and the duodenum is displaced outwards. *a. ao*, aortic arch; *bd. 1*, *bd. 2*, bile-ducts; *b. fabr*, bursa Fabricii; *cbl*, cerebellum; *cæ*, right cœcum; *cpdm*, coprodæum; *cr*, cere; *crb. h*, left cerebral hemisphere; *crp*, crop; *cr. v. 1*, first cervical vertebræ; *di. cæ*, diacœle; *dnt*, dentary; *duo*, duodenum; *eus. ap*, aperture of Eustachian tubes; *giz*, gizzard (dotted behind the liver); *gl*, glottis; *gul*, gullet; *ilm*, ilium; *i. orb. sp*, inter-orbital septum; *kd*, right kidney; *lng*, right lung; *lr*, liver (right lobe); *na*, bristle passed from nostril into mouth; *obl. sep*, oblique septum; *o. gl*, oil gland; *pcd*, pericardium; *pmx*, pre-maxilla; *pn*, pancreas; *pn. b*, pineal body; *pnd. 1–3*, pancreatic ducts; *pr. cv*, right pre-caval; *prdm*, proctodæum; *prvn*, proventriculus (dotted behind liver); *pt. cv*, post-caval; *pty. b*, pituitary body; *pyg. st*, pygostyle; *r. au*, right auricle; *r. br*, right bronchus; *rct*, rectum; *r. vnt*, right ventricle; *sp. cd*, spinal cord; *spl*, spleen (dotted behind liver); *s. rhb*, sinus rhomboidalis; *s. scr*, syn-sacrum; *st*, carina sterni; *syr*, syrinx; *th. v. 1*, first, and *th. v. 5*, fifth thoracic vertebræ; *tng*, tongue; *tr*, trachea; *ts*, right testis; *ur*, aperture of left ureter; *urdm*, urodæum; *v. df*, aperture of left vas deferens.

The *duodenum* (*duo*) leaves the gizzard quite close to the entrance of the proventriculus and forms a distinct loop enclosing the pancreas. The rest of the small intestine is called the *ilium* (*ilm*) : it passes without change of diameter into the *rectum* or large intestine (*rct*), the junction between the two being marked only by a pair of small blind pouches or *cœca* (*cœ*). The *cloaca* is a large chamber divided into three compartments.

There are small *buccal glands* opening into the mouth, but none that can be called salivary. The *liver* (*lr*) is large, and is divisible into right and left lobes, each opening by its own duct (*b. d. 1*, *b. d. 2*), into the duodenum : there is no gall bladder. The *pancreas* (*pn*) is a compact reddish gland lying in the loop of the duodenum, into which it discharges its secretion by three ducts (*pn. d. 1–3*). A thick-walled glandular pouch, the *bursa Fabricii* (*b. fabr*), lies against the dorsal wall of the cloaca in young birds, and opens into the cloaca : it atrophies in the adult.

The *spleen* (*spl*) is an ovoid red body, of unusually small proportional size, attached by peritoneum to the right side of the proventriculus. There are paired *thyroids* at the base of the neck ; and, in young pigeons, there is an elongated *thymus* on each side of the neck. The *adrenals* (Fig. 292, *adr*) are irregular yellow bodies placed at the anterior ends of the kidneys.

The *glottis* (Fig. 287, *gl*) is situated just behind the root of the tongue and leads into the *larynx*, which is supported by cartilages, but does not, as in other vertebrates, function as the organ of voice. From the larynx an elongated tube, the *trachea* or windpipe, the wall of which is supported by numerous bony rings, runs back along the ventral aspect of the neck to enter the body-cavity, where it divides into the right (*r. br*) and left *bronchi*, one passing to each of the lungs.

At the junction of the trachea with the bronchi is found the characteristic vocal organ, the *syrinx* (*syr*), occurring in no other class.

The *lungs* (Fig. 287, *lng*) are very small in comparison with the size of the bird, and are but slightly distensible, being solid, spongy organs, not mere bags with sacculated walls, as in Amphibia and many reptiles. Their dorsal surfaces fit closely into the spaces between the ribs and have no peritoneal covering; their ventral faces are covered by a strong sheet of fibrous tissue, the *pulmonary aponeurosis* or *pleura*, a special development of the peritoneum. Into this membrane are inserted small, fan-like *costo-pulmonary muscles*, which arise from the junction of the vertebral and sternal ribs.

Each main bronchus gives off secondary bronchi, and these branch again, sending off tubes which end blindly near the surface of the lung and give off blind dilations commonly known as *alveoli*. In addition to these, each main bronchus also gives off branches which end in a series of thin-walled *air-sacs*, which lie in the body-cavity, and are in communication with the pneumatic cavities of the bones.

The *heart* (Fig. 288) is of great proportional size, and like that of the crocodile consists of four chambers, *i.e.*, the right and left auricles, and right and left ventricles. There is no sinus venosus, that chamber being, as it were, absorbed into the right auricle (Fig. 288, A, *r. au*). The right ventricle (Fig. 288, B) partly encircles the left, the former having a crescentic, the latter a circular cavity in transverse sections. The left auriculo-ventricular valve has the usual membranous structure consisting of two flaps connected with the wall of the ventricle by tendons, but the corresponding valve of the right side (R. V) is a large muscular fold, very characteristic of the class.

The right auricle receives the right and left pre-cavals (*r. prc*, *l. prc*) and the post-caval (*ptc*), the left, four large pulmonary veins (*p. v*). The left ventricle (Fig. 288, *l. vn*), as in the crocodile, gives origin to the right aortic arch (*a. ao*), but the right ventricle (*r. vn*) gives off only one trunk, the pulmonary artery, which soon divides into two (*r. p. a.*, *l. p. a*). The left aortic arch is absent in the adult, and it is the right alone which is continued into the dorsal aorta. The result of this is that the systemic arteries receive pure arterial blood from the left side of the heart, and the only mingling of aërated and non-aërated blood is in the

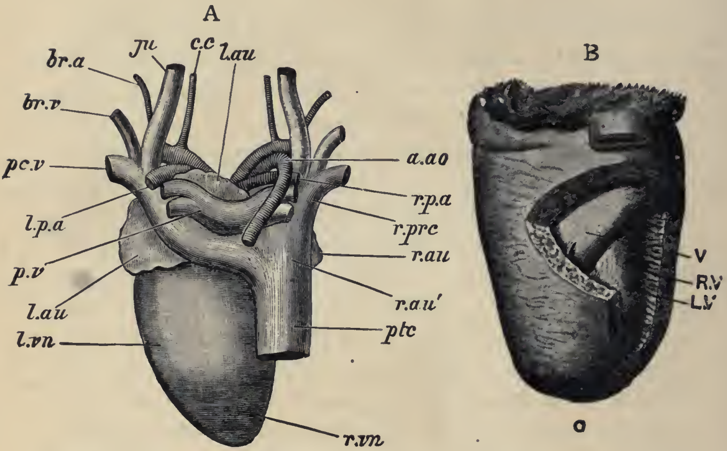

FIG. 288.—A, heart of the pigeon, dorsal aspect. *a. ao*, arch of aorta; *br. a*, brachial artery; *br. v*, brachial vein; *c. c*, common carotid; *ju*, jugular; *l. au*, left auricle; *l. p. a*, left pulmonary artery; *l. vn*, left ventricle; *pc. v*, left pre-caval; *ptc*, post-caval; *p. v*, pulmonary veins; *r. au. r. au'*, right auricle; *r p. a*, right pulmonary artery; *r. prc*, right pre-caval; *r. vn*, right ventricle. B, heart of a bird with the right ventricle opened. L. V, septum ventriculorum; R. V, right ventricle; V, right auriculo-ventricular valve. (A, from Parker's *Zootomy;* B, from Headley's *Birds*.)

capillaries. This is perhaps the most important physiological advance made by birds over reptiles.

The aortic arch curves over the right bronchus to reach the dorsal body-wall, and then passes directly backwards as the dorsal aorta.

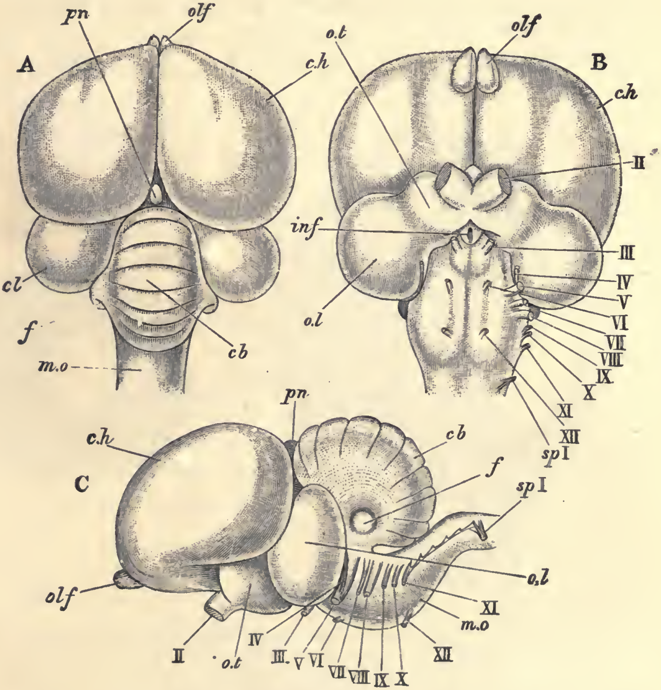
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FIG. 289. — **Columba livia**. The brain; A, from above; B, from below; C, from the left side. *cb*, cerebellum; *c. h*, cerebral hemispheres; *f*, flocculus; *inf*, infundibulum; *m. o*, medulla oblongata; *o. l*, optic lobes; *o. t*, optic tracts; *pn*, pineal body; II–XIII, cerebral nerves; *sp. 1*, first spinal nerve. (From Parker's *Zootomy*.)

The *brain* completely fills the cranial cavity, and is remarkable for its short, broad, rounded form. The *cerebellum*

(Fig. 289, *c. b*) is of great size, and has a large median portion and two small lateral lobes or *flocculi* (*f*); the surface of the middle lobe is marked by grooves passing inwards in a radiating manner and carrying with them the grey matter, the extent of which is thus greatly increased. The *hemispheres* (*c. h*) extend backwards to meet the cerebellum, and the *optic lobes* (*o. l*) are thereby pressed outwards so as to take up a lateral instead of the usual dorsal position.

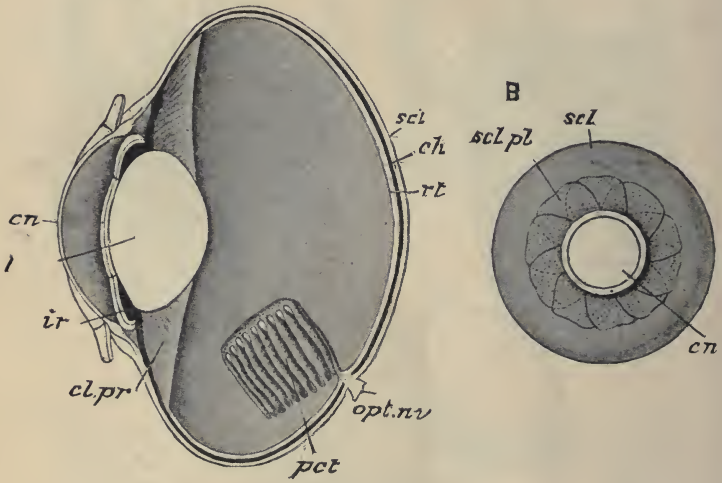

FIG. 290 —The eye. A, in sagittal section; B, the entire organ, external aspect; *cn*, cornea; *ch*, choroid; *cl. pr*, ciliary processes; *ir*, iris; *l*, lens; *opt. nv*, optic nerve; *pct*, pecten; *rt*, retina; *scl*, sclerotic; *scl. pl*, sclerotic plates. (After Vogt and Yung.)

The *eye* (Fig. 290) is not even approximately globular, but has the form of a biconvex lens. *Sclerotic plates* are present, and there is a large *pecten* in the form of a plaited and strongly pigmented membrane projecting into the cavity of the eye from the entrance of the optic nerve.

The *auditory organ* (Fig. 291) is chiefly distinguished from that of reptiles by the great development of the *cochlea*. The tympanic cavity and columella have the same arrangement as in the frog; the narrow Eustachian tubes open by a common aperture (Fig. 287, *eus. ap*) in the roof of the pharynx.

The *kidneys* (Fig. 287, *kd*, Figs. 292 and 293, *k*) have a very characteristic form. Each is a flattened organ divided into three main lobes and fitted closely into the hollows of the pelvis. The *ureters* (*ur*) are narrow tubes passing directly backwards to open into the middle compartment, or the cloaca.

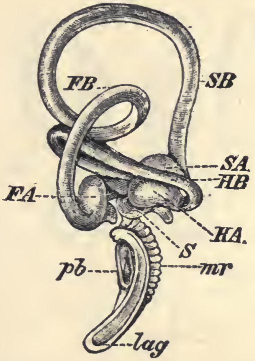

FIG. 291. — **Columba livia.** The right membranous labyrinth, outer aspect; *FA*, ampulla of posterior canal; *FB*, posterior canal; *HA*, ampulla of horizontal canal; *HB*, horizontal canal; *lag*, cochlea or lagena; *mr*, membrane of Reissner; *ph*, basilar part of cochlea; *S*, sacculus; *SA*, ampulla of anterior canal; *SB*, anterior (canal. From Wiedersheim, after Hasse.)

The *testes* (Figs. 287 and 292, *ts*) are ovoid bodies, varying greatly in size according to the season, attached by the peritoneum to the ventral surfaces of the anterior ends of the kidneys. From the inner border of each goes off a convoluted *vas deferens* (*vd*), which passes backwards, parallel with the ureter, to open into the cloaca on the extremity of a small papilla. The posterior end of the spermiduct is slightly enlarged to form a *vesicula seminalis* (*v.s*). The female organs (Fig. 293) are remarkable for the more or less complete atrophy of the right ovary and oviduct.

The *left ovary* (*ov*) is a large organ in the adult bird, its surface studded with follicles or ovisacs, varying in size from about 15 mm. in diameter downwards, and each containing a single ovum. The *left oviduct* (*l. od*) is long and convoluted; its anterior end is enlarged to form a wide, membranous cœlomic funnel (*l. od''*) into which the ripe ova pass on their liberation from the ovisacs; the rest of the tube has thick, muscular walls, lined with glandular epithelium, and opens into the urodæum.

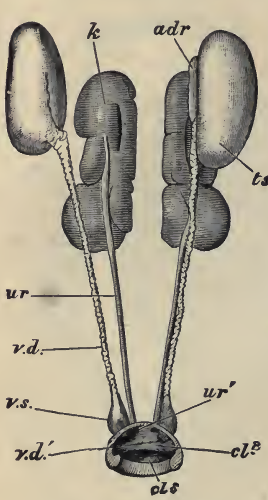

FIG. 292.—**Columba livia** Male urino-genital organs. *adr*, adrenal; *cl. 2*, urodæum; *cl. 3*, proctodæum; *k*, kidney; *ts*, testis, that of the right side displaced; *ur*, ureter; *ur'*, aperture of ureter; *vd*, vas deferens; *vd'*, its cloacal aperture; *v. s*, vesicula seminalis. (From Parker's *Zootomy*.)

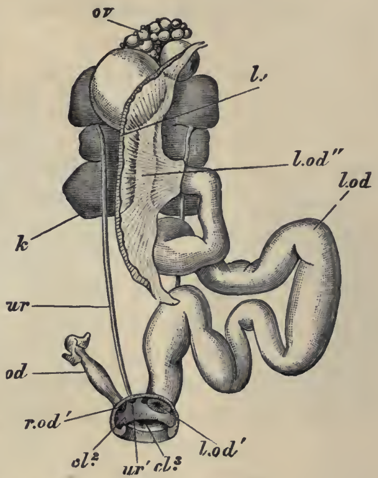

FIG. 293.—**Columba livia.** Female urino-genital organs. *cl. 2*, urodæum; *cl. 3*, proctodæum; *k*, kidney; *l. od*, left oviduct; *l. od'*, its cloacal aperture; *l. od''*, its cœlomic funnel; *l. od'''*, its cœlomic aperture; *ov*, ovary; *r. od*, right oviduct; *r. od'*, its cloacal aperture: *ur*, ureter; *ur'*, its cloacal aperture. (From Parker's *Zootomy*.)

Internal impregnation takes place. As the ova or "yolks" pass down the oviduct, they are invested with the secretions of its various glands; first with layers of *albumen* or "white," next with a parchment-like shell-membrane, and lastly with a white calcareous *shell.* They are laid, two at a time, in a rough nest, and are *incubated* or sat upon by the parents for fourteen days, the temperature being in this way kept at about 40° C. (104° F.). At the end of incubation the young bird is sufficiently developed to break the shell and begin free life. It is covered with fine down, and is fed by the parents with a secretion from the crop, the so-called "pigeon's milk."

Of recent birds two main divisions are recognised—the **Ratitæ** and the **Carinatæ**—the former comprising only the emus (*Dromæus*), cassowaries (*Casuarius*), and kiwis (*Apteryx*), the South American ostriches (*Rhea*), and the true ostriches (*Struthio*); and the latter including all the rest.

One of the most characteristic features of birds in general is the covering of feathers—peculiar epidermal structures which differ widely in shape and arrangement from their equivalents, the horny scales of reptiles and the hairs of mammals. The arrangement of the feathers follows closely that briefly described as observable in the pigeon, with great diversity in detail. The distribution of the contour feathers in feather tracts or pterylæ separated from one another by featherless tracts or *apteria* is almost universal in the Carinatæ, but is not distinguishable in the Ratitæ except in the young condition. In many birds each feather has a secondary vein or *after-shaft,* as it is termed, springing from the main shaft near the umbilicus, and sometimes (Fig. 294) this may be as large as the main shaft itself. A shedding or "moulting" of the feathers takes place at regular intervals, usually annually—a new set of feathers growing from the pulps of the old ones.

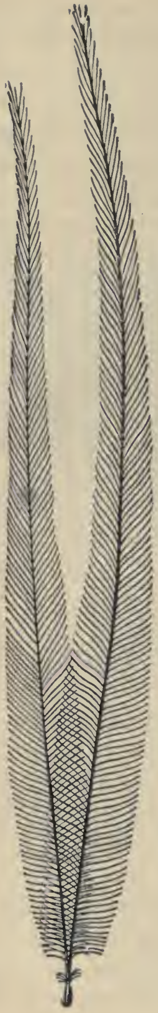

Fig. 294.—**Casuarius** (Cassowary). Feather, showing after-shaft and disconnected barbs. (From Headley.)

The *colours* of feathers present great variety. Black, brown, red, orange, and yellow colours are due to the presence of definite pigments, *i.e.* are absorption colours. White, and in some cases yellow, is produced by the total reflection of light from the spongy, air-containing substance of the feather, there being, as in nearly all other natural objects, no such thing as a white pigment. Blue, violet, and in some cases green, are produced by the light from a brown pigment becoming broken up as it passes through the superficial layer of the feathers in its passage to the eye ; no blue or violet pigments occur in feathers, and green pigments are very rare. The beautiful metallic tints of many birds are entirely the result of structure, owing their existence to a thin, transparent, superficial layer, which acts as a prism : in such feathers the colour changes according to the relative position of the bird and of the eye of the observer with regard to the source of light.

There is also infinite variety in the general coloration of birds. In many the colouring is distinctly protective, harmonising with the environment, and even changing with the latter, as in the ptarmigan, which is greyish brown in summer, white in winter, the former hue helping to conceal the bird among herbage, the latter on snow. Frequently, as in pheasants and birds of paradise, the female alone is protectively coloured, while the male presents the most varied and brilliant tints enhanced by crests, plumes or tufts of feathers on the wings, elongated tail, etc. etc. These have been variously explained as "courtship colours" for attracting the female; as due simply to the exuberant vitality of the male bird, or as helping to keep the number of males within proper limits by rendering them conspicuous to their enemies. Such ornaments as the bars and spots on the wings and tail of many gregarious birds, such as plovers, fully exposed only during flight, and often widely different in closely allied species, have been explained as "recognition marks," serving to enable stragglers to distinguish between a flock of their own and of some other species.

The toothless jaws with the horny sheaths forming the bill are universal in the class. But the dimensions and form of the bill vary very widely in different groups of birds. It may be extremely short and wide for catching moths and other flying insects, as in swifts and goatsuckers; short and conical for eating fruit, as in finches; strongly hooked for tearing the bodies of animals, as in birds of prey, or for rending fruits of various kinds, as in parrots; long, conical, and of great strength, as in storks; slender and elongated, as in swifts, ibises, and curlews; broad and flattened for feeding in mud, as in ducks and geese; expanded at the end, as in spoonbills; immensely enlarged, as in hornbills and toucans. It is most commonly bent downwards at the tip, but may be straight or curved upwards, as in the avocet, or bent to one side, as in the New Zealand crook-billed plover. It is sometimes, as in the toucans, brilliantly coloured, and there may also be bright coloration of the cere, as in the macaws, and of naked spaces on the head, as in the cassowaries. In the latter the head is produced into a great horny prominence or "casque," supported by an elevation of the roof of the skull. The cere is frequently absent. The nostrils are placed at the base of the beak, except in Apteryx, in which they are at the tip.

The essential structure of the wing — apart from its feathers — is very uniform. As a rule all three digits are devoid of claws, as in the pigeon, but the ostrich has claws on all three digits; rhea on the first, and sometimes the second and third; the cassowary, emu, and kiwi (Fig. 295, B) on the second; and the crested screamer (*Chauna*) and two other species, and, as a rare abnormality, the common fowl and the goose, on the first. With these exceptions, the

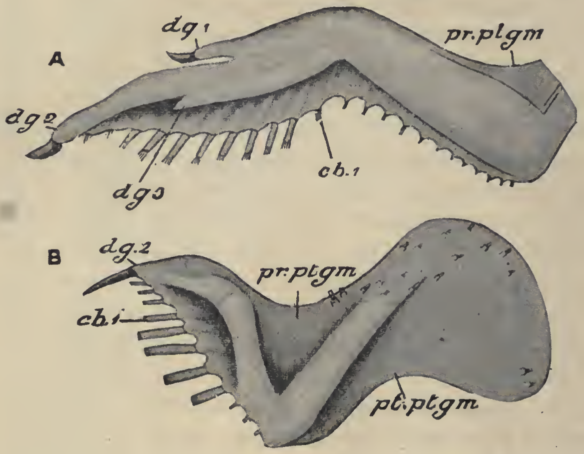

Fig. 295. — A, wing of nestling of *Opisthocomus;* B, wing of adult *Apteryx;* both from the inner (ventral) aspect; *cb. 1*, first cubital remex; *dg. 1*, *dg. 2*, *dg. 3*, digits; *pr. ptgm*, pre-patagium; *pt. pgm*, post-patagium. (A, after Pycraft; B, after T. J. Parker.)

hand of the adult bird has lost all the characters of a forefoot; but in the young of the hoatzin (*Opisthocomus*) claws are present on the first two digits (Fig. 295, A), which are sufficiently mobile to be used in climbing. Besides the true claws, horny *spurs* are sometimes present on the carpus and metacarpus.

There is almost every gradation in the proportional length of the hind-limb, from birds in which nothing but the foot projects beyond the contour feathers, and even the toes may be feathered, to the long-legged storks and cranes, in which the distal part of the tibio-tarsus is covered with scales as well as the foot. In aquatic forms a fold of skin or *web* is stretched between the toes, sometimes including all four digits, as in the cormorants; sometimes leaving the hallux free, sometimes forming a separate fringe to each digit, as in the coots and grebes. As to the toes themselves, the commonest arrangement is for the hallux to be directed backwards, and Nos. 2, 3, and 4 forwards, but in the owls No. 4 is reversible, *i.e.* can be turned in either direction, and in the parrots, woodpeckers, etc., it, as well as the hallux, is permanently turned backwards. In the swifts, on the other hand, all four toes turn forwards. The hallux is frequently vestigial or absent, and in the ostrich No. 4 has also atrophied, producing the characteristic two-toed foot of that bird.

The following are the most essential general features of the skeleton of birds. More or fewer vertebræ from the regions in front of and behind the sacral fuse with the true sacral vertebræ to form the composite syn-sacrum. The posterior caudal vertebræ are fused together to form a *pygostyle*. The bones of the skull early unite, the sutures becoming entirely obliterated. There is a single rounded occipital condyle. The premaxillæ are very large and form the greater part of the upper jaw. The sternum is broad, and is usually provided with a prominent keel or carina as in the pigeon, but the carina is absent in the Ratitæ, and is rudimentary or absent in some flightless Carinatæ. The clavicles and interclavicle unite to form a furcula. The distal carpals and metacarpals unite to form a carpo-metacarpus. The pubes and ischia run downwards and backwards parallel with one another; and neither the pubes nor the ischia unite in a symphysis, but remain widely separated at their distal ends, except in the ostrich, in which the pubes unite distally, and the South American ostriches in which the ischia unite while the pubes remain free. Universally characteristic of the skeleton of the hind-limb is the union of the tibia with the proximal element of the tarsus to form a tibio-tarsus, and of the distal element of the tarsus with the second, third, and fourth metatarsals to form a tarso-metatarsus, the ankle-joint being situated between these bones. The skeleton always contains air-cavities to a greater or less extent.

The presence of crop, proventriculus, and gizzard, as in the pigeon, is universal among birds. The gizzard is most powerful in grain-eating birds, thinner-walled in flesh-eaters. There is a pair of cœca in most birds at the junction of the large and small intestines. The voice of birds is always produced not in the larynx, as in other higher vertebrates, but in a syrinx situated either, as in the pigeon, at the junction of the trachea and bronchi, or at the anterior ends of the bronchi, or the posterior end of the trachea. The system of air-sacs connected with the bronchi described in the account of the pigeon is of universal occurrence.

The temperature of the blood is always high. The heart in all has the same main features as in the pigeon: it has four distinct chambers, two auricles and two ventricles, and there is a single aortic arch, situated on the right side. In the brain the most characteristic points are the short rounded hemispheres, the large folded cerebellum produced forwards to meet the hemispheres, and the laterally placed optic lobes. The internal ear has a large curved cochlea, and the eye has a pecten. The right ovary and oviduct are more or less completely aborted.

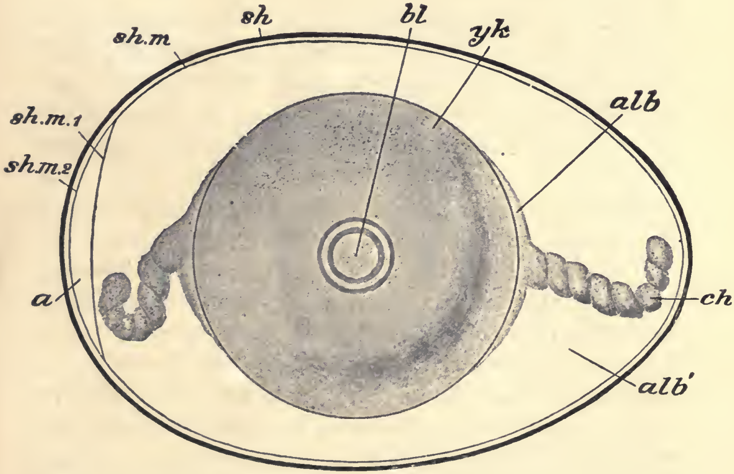

FIG. 296.—**Gallus bankiva** (domestic fowl). Semi-diagrammatic view of the egg at the time of hatching. *a*, air-space; *alb*, dense layer of albumen; *alb'*, more fluid albumen; *bl*, blastoderm; *ch*, chalaza; *sh*, shell; *sh. m*, shell-membrane; *sh. 1*, *sh. 2*, its two layers separated to enclose air-cavity. (From Marshall's *Embryology*, slightly altered.)

The *ovum* is always large, owing to the great quantity of food-yolk; the protoplasm forms a small *germinal disc* at one pole. Impregnation is internal, and as the incipient egg or oosperm passes down the oviduct, it is coated by successive secretions from the oviducal glands. It first receives a coat of thick, viscid *albumen* (Fig. 296, *alb*), which, as the egg rotates during its passage, becomes coiled at either end into a twisted cord, the *chalaza* (*ch*). Next, more fluid albumen (*alb'*) is deposited layer by layer, then a tough, parchment-like *shell-membrane* (*sh. m*) and finally a calcareous *shell* (*sh*). The shell-membrane is double, and at the broad end of the egg the two layers are separate and enclose an air-cavity (*a*). The shell may be white or variously coloured by special pigments: it consists of three layers, and is traversed by vertical pore-canals, which are unbranched in the Carinatæ and in Apteryx, branched in the other Ratitæ.

The eggs may be laid on the bare ground or on the rocks by the seashore, as in penguins and auks, or on the ledges on inaccessible cliffs as in the sooty albatross (*Diomedea fuliginosa*); but as a rule a *nest* is constructed for their reception by the parent birds. This may be simply a hole in the sand, as in the ostrich; a mere clearing on the hill-side surrounded by a low wall of earth, as in the wandering albatross (*Diomedea exulans*); or a cylinder with excavated top, built of grass, earth, and manure, as in the mollymawks (*Diomedea melanophrys*, etc.). It may take the form of a burrow, as in many petrels, kingfishers, and sand-martins, or it may be more or less elaborately built or woven of sticks, moss, leaves, hair, or feathers, showing every stage of constructive skill from the rude contrivance of sticks of the pigeon and eagle, to the accurately constructed cup- or dome-shaped nests of many familiar Passeres. In the tailor-bird (*Orthotomus*) it is formed of leaves sewn together, the beak acting as needle: in a Malayan swift (*Collocalia*) it is largely built of the secretion of the bird's buccal glands.

After the egg is laid, the process of development is arrested unless the temperature is kept up to about 40° C. (104° F.): this is usually done by the heat of the body of the parent birds, one or both of which sit upon, or *incu-*

bate, the eggs until the young are hatched, but in the Australian mound-makers (*Megapodius*) the eggs are buried in heaps of decaying vegetable matter, the decomposition of which generates the necessary heat.

CLASS VI. MAMMALIA

The class Mammalia, the highest of the Vertebrata, comprises the Monotremes and Marsupials, the hoofed and clawed quadrupeds, the whales and porpoises and sea-cows, the rodents, bats, and insectivores, the lemurs and apes, and the human species. All mammals, though many are aquatic, are air-breathers throughout life, lungs being, as in reptiles and birds, the sole organs of respiration. The blood of mammals has a high temperature, resembling in that respect the blood of birds, and differing from that of reptiles and amphibia. The scales of reptiles and the feathers of birds are replaced in mammals by peculiar epidermal structures, the hairs, usually developed in such quantities as to form a thick soft covering or fur.

The rabbit (*Lepus cuniculus*) will serve as a convenient example of the class.[1]

The rabbit (Fig. 297) is a four-footed or quadrupedal animal, having the whole surface of its body covered with soft fur. The head bears below its anterior extremity the mouth in the form of a transverse slit bounded by soft lips. The upper lip is divided by a longitudinal cleft, running backwards to the nostrils and exposing the chisel-shaped *incisor teeth*. Behind the incisor teeth the hairy integument projects on each side into the cavity of the mouth. At the end of the snout, above the mouth, are the nostrils in the shape of two oblique slits. The large eyes, situated at the sides of the head, have each three eyelids, an upper and a lower hairy lid, and an anterior hairless third eyelid or *nictitating membrane*, supported by a plate of cartilage. *Vibrissæ* — very long stiff hairs — are scattered above and below the eyes and on the snout. Behind the eyes and a little nearer the summit of the head, are a pair of very long flexible and movable external ears or *pinnæ.* These are somewhat spout-shaped, expanding distally and are usually placed vertically with the concavity directed laterally and somewhat forwards, leading to the external auditory opening. The *neck* is a distinct constriction, but relatively short as compared with the neck of the pigeon. The *trunk* is distinguishable into *thorax* in front and *abdomen* behind. On the ventral surface of the abdomen in the female are four or five pairs of little papillæ — the *teats.*

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[1] The following account will apply in all but very slight details to our cotton-tail rabbit or to our American hare.

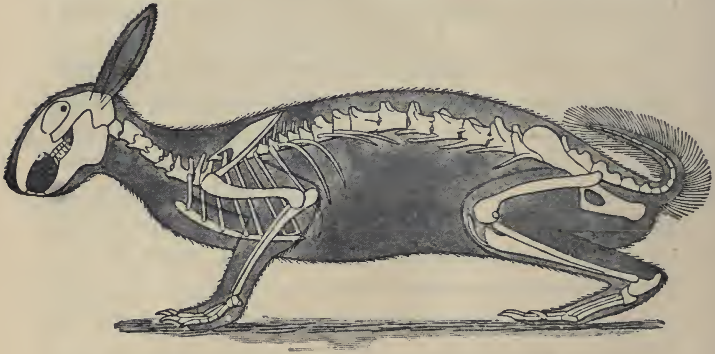

FIG. 297. — **Lepus cuniculus.** Lateral view of skeleton with outline of body.

At its posterior end, below the root of the tail, is the *anal opening*, and in front of this in the male is the *penis*, with a small terminal *urinogenital aperture* and with the *testes*, each in a prominent *scrotal sac*, at the sides : and in the female the opening of the *vulva*. The tail is very short and covered with a tuft of fluffy hair.

The *fore-* and *hind-limbs,* both of which take part in locomotion and in supporting the weight of the animal, differ considerably in size — the fore-limbs being much shorter than the hind-limbs. Both have the same general divisions as in the lizard. The upper arm is almost completely hidden by the skin, being applied closely against the side of the body. The *manus* is provided with five digits, each terminating in a horny claw. The thigh is also almost hidden by the skin; the *pes* has four digits only, all provided with claws.

The *spinal column* of the rabbit is divisible, like that of the pigeon, into five regions — the cervical, the thoracic, the lumbar, the sacral, and the caudal. In the *cervical* region there are seven vertebræ; in the *thoracic* twelve or sometimes thirteen, in the *lumbar* seven, or sometimes six, in the *sacral* four, and in the *caudal* about fifteen.

The centra of the vertebræ in a young rabbit consists of three parts — a middle part, which is the thickest, and two thin discs of bone — the *epiphyses* — anterior and posterior, applied respectively to the anterior and posterior faces of the middle part or centrum proper. Between successive centra in an unmacerated skeleton and thin disc-like plates of fibro-cartilage — are the *inter-vertebral discs.*

The first vertebra or *atlas* (Fig. 298, B) resembles the corresponding vertebra of the pigeon in being of the shape of a ring without any solid centrum like that of the rest. On the anterior face of its lateral portions are two concave articular surfaces (*art*) for the two condyles of the skull. The second vertebra or *axis* (B and C) bears on the anterior face of its centrum a peg-like process — the *odontoid process* (*od*) — which fits into the ventral part of the ring of the atlas.

The thoracic vertebræ all have elongated spines. The transverse processes are short and stout; each bears near its extremity a small, smooth articular surface or *tubercular facet* for the tubercle of a rib. On the anterior and posterior borders of each vertebra is a little semi-lunar facet, the *capitular facet*, situated at the junction of the centrum and the neural arch. The two contiguous semi-lunar facets of successive vertebræ form between them a cup-like concavity into which the head or *capitulum* of a rib is received.

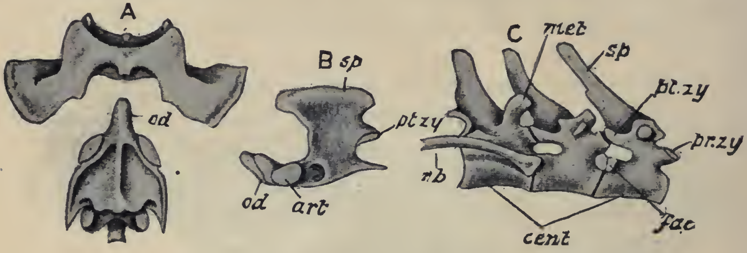

FIG. 298.—**Lepus cuniculus.** A, atlas and axis, ventral aspect. *od*, odontoid process of axis. B, lateral view of axis. *art*, articular facet for occipital condyle; *od*, odontoid process; *pt. zy*, post-zygapophysis; *sp*, neural spine. C, thoracic vertebræ, lateral view. *cent*, centrum; *fac*, facet for rib; *met*, metapophysis; *pr. zy*, prezygapophysis; *pt. zy*, post-zygapophysis; *rb*, rib; *sp*, spinous process.

In the lumbar region the spines are comparatively short, and both transverse processes and bodies are devoid of facets.

The sacral vertebræ are firmly ankylosed together to form a single composite bone, the *sacrum*. The first and second bear great expanded lateral plates — sacral ribs — with roughened external surfaces for articulation with the ilia.

Of the caudal vertebræ the more anterior resemble those of the sacral region and have similar processes; but as we pass backwards in the caudal region all the processes gradually diminish in size, the most posterior vertebra being represented merely by nearly cylindrical centra.

There are twelve pairs of *ribs*, of which the first seven are *true* ribs, *i.e.* are connected by their cartilaginous sternal ribs with the sternum; while the remaining five, the so-called *false* or *floating* ribs, are not directly connected with the sternum. All, except the last four, bear two articular facets, one on the vertebral extremity or *capitulum*, and the other on a little elevation or *tubercle* situated at a little distance from this, the former for the bodies, the latter for the transverse processes of the vertebræ.

The sternum (Fig. 300) consists of six segments or *sternebræ*. The first or *manubrium sterni* or *presternum* is larger than the rest, and has a ventral keel. With the last is connected a rounded cartilaginous plate, the *xiphisternum*.

The *skull* (Fig. 299), if we leave the jaws out of account, is not at all unlike that of the pigeon in general shape. The length is great as compared with either the breadth or the depth; the maxillary region, or region of the snout (corresponding to the beak of the pigeon), is long in proportion to the rest, the orbits closely approximated, being separated only by a thin inter-orbital partition, and the optic foramina united into one. But certain important differences are to be recognised at once. One of these is in the mode of union of the constituent bones. In the pigeon, as we have seen, long before maturity is attained, the bony elements of the skull, originally distinct, become completely fused together so that their limits are no longer distinguishable. In the rabbit, on the other hand, such fusion between elements only takes place in one or two instances, the great majority of the bones remaining distinct throughout life. The lines along which the edges of contiguous bones are united — the *sutures* as they are termed — are sometimes straight, sometimes wavy, sometimes zig-zagged, serrations of the edges of the two bones interlocking; in some cases the edges of the bones are bevelled off, and the bevelled edges overlap, forming what is termed a *squamous* suture.

Another conspicuous difference between the skull of the rabbit and that of the pigeon is in the mode of connection of the lower jaw, which in the former articulates directly with the skull, the quadrate, through which the union is effected in the pigeon, being apparently absent. Certain large apertures which are distinguishable are readily identified with the large openings in the skull of the pigeon. In the posterior wall of the skull is a large rounded opening, the *foramen magnum*, flanked with a pair of smooth rounded elevations or *condyles* for articulation with the first vertebra, these obviously corresponding to the single condyle situated in the middle below the foramen in the pigeon. A large opening situated at the end of the snout and looking forwards obviously takes the place of the *external nares* of the pigeon; and a large opening in the roof of the mouth leading forward to the external nasal opening, plainly represents, though much wider and situated further back, the *internal* or *posterior nares* of the pigeon; while the rounded tubular opening situated at the side of the posterior part of the skull, some distance behind the orbit, is evidently the same as the *auditory aperture* of the pigeon.

Surrounding the large opening of the foramen magnum are the bones of the *occipital* region of the skull, the *supra-ex-* and *basi-occipitals*. The first of these (*s. oc*) is a large plate of bone above the foramen magnum. The *ex-occipitals* lie at the sides of the opening and each bears the greater part of the somewhat oval prominence or condyle with which the corresponding surface of the atlas or first vertebra articulates. The *basi-occipital* is a median plate of bone, almost horizontal

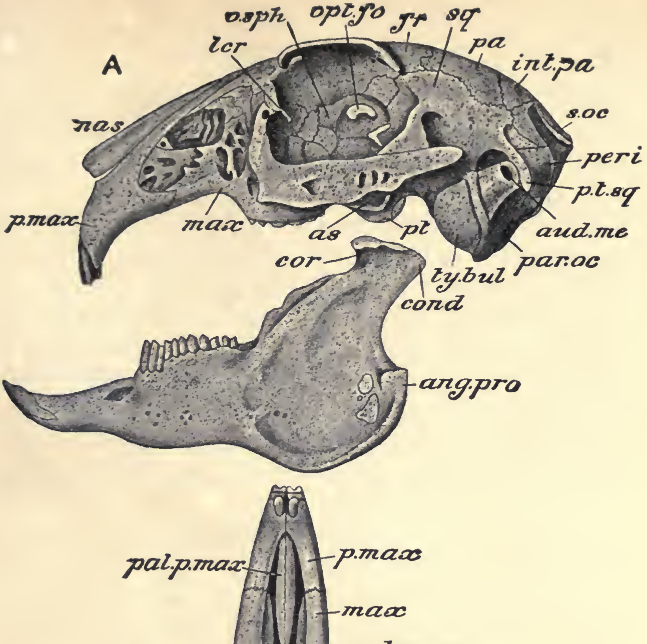
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FIG. 299. — **Lepus cuniculus.** Skull: A, lateral view; B, ventral view. *ang. proc*, angular process of mandible; *as*, ali-sphenoid (external pterygoid process); *b. oc*, basi-occipital; *b. sph*, basi-sphenoid; *cond*, condyle; *fr*, frontal; *int pa*, inter-parietal; *ju*, jugal; *lcr*, lacrymal; *max*, maxilla; *nas*, nasal; *opt. fo*, optic foramen; *o. sph*, orbito-sphenoid; *pa*, parietal; *pal*, palatine; *pal max*, palatine plate of maxilla; *par. oc*, par-occipital process; *pal. p. max*, palatine process of pre-maxilla; *p. max*, pre-maxilla; *per*, periotic; *pt*, pterygoid; *p. t. sq*, post-tympanic process of squamosal; *s. oc*, supra-occipital; *sq*, squamosal; *ty. bul*, tympanic bulla; *vo*, vomer; *zyg. max*, zygomatic process of maxilla.

in position, which forms the floor of the most posterior part of the cranial cavity; it bears the lower third of the occipital condyles. Articulating in front with the basi-occipital is a plate of bone, also horizontal in position, which forms the middle part of the floor of the cranial cavity. This is the *basi-sphenoid;* on its upper surface is a depression, the *sella turcica* or *pituitary fossa*, in which the pituitary body rests. In front of it is another median bone of laterally compressed form, the *pre-sphenoid.* Connected laterally with the basi-sphenoid and pre-sphenoid are two pairs of thin irregular plates, the *ali-sphenoid* (*as*) behind and the *orbito-sphenoid* (*o: sph*) in front. The ali-sphenoids are broad wing-like bones, each produced below into a bilaminate process, the *pterygoid* process.

The boundary of the anterior part of the brain case is completed by a narrow plate of bone, the *cribriform plate* of the *ethmoid*, perforated by numerous small foramina for the passage of the olfactory nerves. This cribriform plate forms a part of a median vertical bone, the *mesethmoid*, the remainder of which, or *lamina perpendicularis*, forms the bony part of the partition (completed by cartilage in the unmacerated skull) between the nasal cavities. Fused with the mesethmoid are two lateral, thin-twisted bones, the *ethmo-turbinals*, and with its inferior edge articulates a long median bone with a pair of delicate lateral wings, the *vomer*. Roofing over the part of the cranial cavity, the walls and floors of which are formed by the sphenoid elements, is a pair of membrane bones, the *parietals* (*pa*), and further forward another pair, the *frontals* (*fr*). Between the supra-occipital and the parietals is a median ossification, the *inter-parietal* (*int. pa*). Below the parietal and frontal is a broad bone (*sq*), the superior margin of which is bevelled off. This is the *squamosal.* It gives off in front a strong *zygomatic process*, which curves outwards, then downwards, and finally forwards, to unite with the *jugal* in the formation of the *zygomatic arch*. Below the root of the process is a hollow, the *glenoid fossa*.

Between the occipital and parietal bones, below and behind the squamosal, are the *tympanic* and *periotic* bones. The tympanic forms the bony part of the wall of the external auditory meatus; below it is dilated to form a process (*ty. bul*) projecting on the under surface of the skull, the *bulla tympani*. The periotic (*p. ot*) is a bone of irregular shape enclosing the parts of the membranous labyrinth of the internal ear; externally it presents two small openings, the *fenestra ovalis* and *fenestra rotunda*, visible only when the tympanic is removed. The periotic and tympanic are ankylosed together, but are loosely connected with the surrounding bones.

Roofing over the olfactory cavities are two flat bones, the *nasals* (*nas*). In front of the nasals are the *pre-maxillæ* — large bones which form the anterior part of the snout, bear the upper incisor teeth, and give off three processes. The *maxillæ* (*max*), which form the greater part of the upper jaw and bear the premolar and molar teeth, are large, irregularly shaped bones, the upper surfaces of which are spongy. They give off internally horizontal processes, the *palatine processes*, which unite to form the anterior part of the bony palate. A strong process which is given off from the outer face of each maxilla and turns outwards and then backwards to unite with the zygomatic process of the squamosal and thus complete the zygomatic arch, is a separate bone in the young, the *malar* or *jugal* (*ju*).

The rest of the narrow bony palate, forming the roof of the mouth and the floor of the nasal cavities, is formed by the *palatine plates* of the *palatine bones*. The *pterygoids* are small irregular bones, each of which articulates with the palatine in front and the ali-sphenoid behind. The *lachrymals* are small bones, one situated in the anterior wall of each orbit, perforated by a small aperture — the *lachrymal foramen.*

The *mandible*, or lower jaw, consists of two lateral halves or *rami*, which articulate with one another in front by a rough articular surface or *symphysis*, while behind they diverge like the limbs of a letter V. In each ramus is a horizontal portion (anterior), which bears the teeth, and a vertical or ascending portion, which bears the articular surface or *condyle* for articulation with the glenoid cavity of the squamosal; in front of the condyle is the compressed *coronoid process.* The angle where the horizontal and ascending processes meet gives off an inward projection or *angular process.*

The *hyoid*, which, as in the pigeon, is the only other post-oral visceral arch represented in the adult, consists of a stout thick body or *basi-hyal*, a pair of small anterior cornua or *cerato-hyals*, and a pair of long backwardly directed cornua or *thyro-hyals.*

The *auditory ossicles*, contained in the cavity of the middle ear, and cut off from the exterior, in the unmacerated skull, by the tympanic membrane, are extremely small bones, which form a chain extending, like the columella auris of the pigeon, from the tympanic membrane externally to the fenestra ovalis internally.

The elements of the *pectoral arch* (Fig. 300) are fewer than in the pigeon. There is a broad thin triangular scapular, the base or vertebral edge of which has a thin strip of cartilage (the *supra-scapular* cartilage) continuous with it. Along the outer surface runs a ridge, the *spine;* the spine ends below in a long process, the *acromion process* (*a*), from which a branch process or *metacromion* (*ma*) is given off behind. At the narrow lower end of the scapula is a concave surface, the *glenoid cavity*, into which the head of the humerus fits, and immediately in front of this is a small inwardly curved process, the *coracoid process* (*c*), which is represented by two separate ossifications in the young rabbit. A slender rod, the *clavicle* (*cl*), is connected with the acromion process externally and with the sternum internally by means of fibrous tissue.

At the proximal end of the humerus are to be recognised: (1) A rounded head for articulation with the glenoid cavity of the scapula; (2) externally a *greater;* and (3) internally a *lesser tuberosity* for the insertion of muscles. At the distal end are two articular surfaces, one large and pulley-like, *trochlea*, for the ulna; the other smaller, *capitellum*, for the radius: laterally are two prominences or *condyles*, an internal and an external.

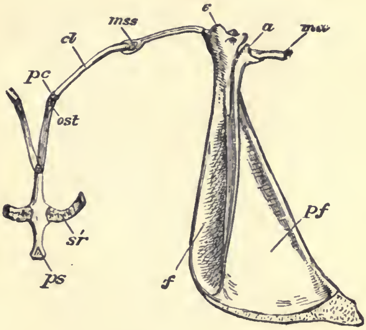

FIG. 300. — **Lepus cuniculus.** Shoulder-girdle with anterior end of sternum of young specimen. *a*, acromion; *af*, pre-scapular fossa; *c*, coracoid; *cl*, ossified clavicle; *ma*, metacromion; *mss*, meso-scapular segment; *ost*, pre-sternum; *pc*, pre-coracoid; *pf*, post-scapular fossa; *sr*, sternal ribs. (After Flower.)

The radius and ulna are firmly fixed together so as to be incapable of movement, but not actually ankylosed. The radius articulates proximally with the humerus, distally with the scaphoid and lunar bones of the carpus. The ulna presents on the anterior aspect of its proximal end a deep fossa, the *greater sigmoid cavity*, for the trochlea of the humerus; the prominent process on the proximal side of this is the *olecranon* process. Distally it articulates with the cuneiform.

The carpal bones (Fig. 301), nine in number, are all small bones of irregular shape. Eight of these are arranged in two rows, a proximal and a distal; the ninth, *centrale* (*cent*), lies between the two rows. The bones of the proximal row are — taken in order from the inner to the outer side — *scaphoid* (*sc*), *lunar* (or *semi-lunar*) (*lun*), *cuneiform* (*cun*), and *pisiform*. Those of the distal row are reckoned in the same order, *trapezium* (*trpm*), *trapezoid* (*trpz*), *magnum* (*mag*), and *unciform* (*unc*).

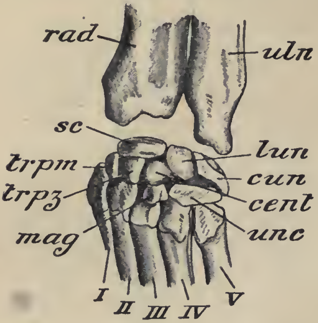

FIG. 301. — **Lepus cuniculus.** Distal end of fore-arm and carpus, dorsal view, the bones bent towards the dorsal side so as to be partly separated: *cent*, centrale; *cun*, cuneiform; *lun*, lunar; *mag*, magnum; *rad*, radius; *sc*, scaphoid; *trpz*, trapezoid; *trpm*, trapezium; *uln*, ulna; *unc*, unciform; *I–V*, bases of metacarpals. (After Krause.)

The five metacarpals are all small but relatively narrow and elongated bones, the first being smaller than the rest. Each of the five digits has three phalanges, except the first which has only two. The distal (ungual) phalanges are grooved dorsally for the attachment of the horny claw.

The pelvic arch (Fig. 302) contains the same elements as in the pigeon, but the union of the ilium with the sacrum is less intimate, the acetabulum is not perforated, and the pubes of opposite sides unite ventrally in a *symphysis* (*sy*). The ilium and ischium meet in the acetabulum or articular cavity, which they contribute to form for the head of the femur, but the remainder of the cavity is bounded, not by the pubis, but by a small intercalated ossification, the *cotyloid* bone. The *ilium* (*il*) has a rough surface for articulation with the sacrum. Between the *pubis* (*pub*) in front and the *ischium* (*isch*) behind is a large aperture, the *obturator foramen* (*obt*). The femur has at its proximal end a prominent *head* for articulation with the acetabulum, external to this a prominent process, the *great trochanter*, and internally a much smaller, the *lesser trochanter*, while a small process or *third trochanter* is situated on the outer border a little below the great trochanter. At its distal end are two prominences or *condyles*, with a depression between them. Opposite the knee-joint, or articulation between the femur and the tibia, is a small bone or knee-cap, the *patella*. The tibia has at its proximal end two articular surfaces for the condyles of the femur; distally it has also two articular surfaces, one, internal, for the astragalus, the other for the calcaneum. The fibula is a slender bone which becomes completely fused distally with the tibia.

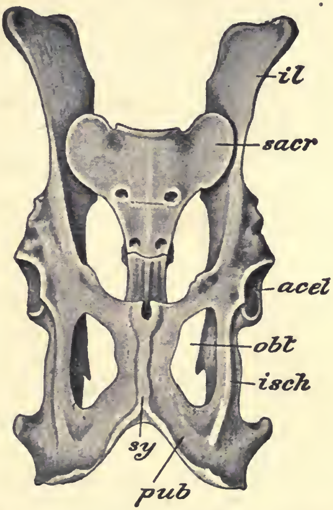

FIG. 302. — **Lepus cuniculus.** Innominate bones and sacrum, ventral aspect. *acet*, acetabulum; *il*, ilium; *isch*, ischium; *obt*, obturator foramen; *pub*, pubis; *sacr*, sacrum; *sy*, symphysis.

The tarsus consists of six bones of irregular shape arranged in two rows, one of the bones, the *navicular* (Fig. 303, *nav*), being intercalated between the two rows.

In the proximal row are two bones, the *astragalus* (*ast*) and the *calcaneum* (*cal*), both articulating with the tibia; the calcaneum presents behind a long *calcaneal process*. The distal row contains three bones, the *mesocuneiform*, *ectocuneiform*, and *cuboid* (*cub*); the *entocuneiform*, which commonly forms the most internal member of this row in other mammals, is not present as a separate bone.

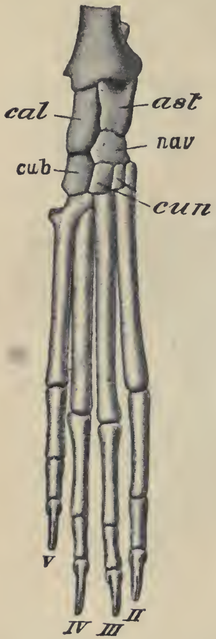

FIG. 303.—**Lepus cuniculus.** Skeleton of pes; *ast*, astragalus; *cal*, calcaneum; *cub*, cuboid; *cun*, cuneiforms; *nav*, navicular.

There are four metatarsals, the hallux or first digit being absent. Each of the digits has three phalanges, which are similar in character to those of the manus.

The cœlom of the rabbit differs from that of the pigeon in being divided into two parts by a transverse muscular partition, the *diaphragm*. The anterior part, or *thorax*, contains the heart and the roots of the great vessels, the lungs and bronchi, and the posterior part of the œsophagus. The posterior part or *abdomen* contains the stomach and intestine, the liver and pancreas, the spleen, the kidneys, ureters and urinary bladder, and the organs of reproduction.

The teeth (Fig. 299) are lodged in sockets or *alveoli* in the pre-maxillæ, the maxillæ, and the mandible. In the pre-maxillæ are situated four teeth, the four *upper incisors*. Of these the two anterior are very long, curved, chisel-shaped teeth, which are devoid of roots, growing throughout life from persistent pulps. Enamel is present as a thick layer on the anterior convex surface only, which accounts for the bevelled-off character of the distal end, the layer of enamel being much harder than the rest, which therefore wears more quickly away at the cutting extremity of the tooth. The second pair of incisors of the upper jaw are small teeth which are lodged just behind the larger pair. In the lower jaw are two incisors, which correspond in shape with the anterior pair of the upper jaw. The remaining teeth of the upper jaw are lodged in the maxillæ. *Canines*, present in most mammals as a single tooth on each side, are here entirely absent, and there is a considerable space, or *diastema*, as it is termed, between the incisors and the teeth next in order, the *pre-molars*. Of these there are three in the upper jaw and two in the lower. They are long, curved teeth devoid of fangs, the first smaller than the others. Behind the pre-molars are the *molars*, three on each side both in the upper and lower jaws.

Opening into the cavity of the mouth are the ducts of four pairs of salivary glands. On the floor of the mouth is the muscular tongue, covered with a mucous membrane which is beset with many papillæ. The roof of the mouth is formed by the *palate*. The anterior part, or *hard palate*, is crossed by a series of transverse ridges of its mucous membrane. The posterior part, or *soft palate*, ends behind in a free pendulous flap (the *uvula*) in front of the opening of the *posterior nares*. Behind the mouth or buccal cavity proper is the *pharynx*. The pharynx is divided into two parts, an upper or *nasal* division, and a lower or *buccal* division, by the soft palate. Into the nasal division open in front the two posterior nares and at the sides the openings of the *Eustachian tubes*. The nasal division is continuous with the buccal division round the posterior free edge of the soft palate. From the buccal division leads ventrally the slit-like opening of the glottis into the larynx and trachea; overhanging the glottis is a leaf-like movable flap (Fig. 304, *ep*) formed of a plate of yellow elastic cartilage covered with mucous membrane: this is the *epiglottis*. Behind, the pharynx becomes continuous with the *œsophagus* or gullet (*œs*). The latter is a narrow but dilatable muscular tube, which runs backwards from the pharynx through the neck and thorax to enter the cavity of the abdomen through an aperture in the diaphragm, and opens into the *stomach*.

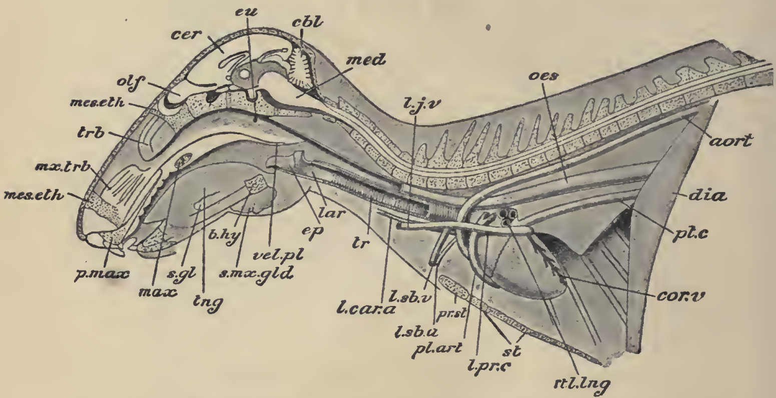

FIG. 304.—**Lepus cuniculus.** Lateral dissection of the head, neck, and thorax. The head and spinal column are represented in mesial vertical section; the left lung is removed; the greater part of the nasal septum is removed so as to show the right nasal cavity with its turbinals. *aort*, dorsal aorta; *b. hy*, basi-hyal; *cbl*, cerebellum; *cer*, cerebral hemispheres; *cor. v*, coronary vein; *dia*, diaphragm; *ep*, epiglottis; *eu*, opening of Eustachian tube into pharynx; *lar*, larynx; *l. j. v*, left jugular vein; *l. sb. a*, left subclavian artery; *l. sb. v*, left subclavian vein; *med*, medulla; *mes. eth*, mesethmoid; *mx. trb*, maxilla-turbinal; *œs*, œsophagus; *olf*, olfactory lobe; *pl. a*, pulmonary artery; *p. max*, pre-maxilla; *pr. st*, presternum; *pt. c*, post-caval vein; *rt. lng*, root of left lung with bronchus and pulmonary veins and artery cut across; *s. gl*, sub-lingual salivary gland; *s. mx. gld*, sub-maxillary salivary gland; *st*, sternebræ; *tng*, tongue; *tr*, trachea; *trb*, ethmo-turbinals; *vel. pl*, soft palate.

The stomach (Fig. 305) is a wide sac, much wider at the end (*cardiac*), at which the œsophagus enters, than at the opposite or *pyloric* end, where it passes into the small intestine. The small intestine is an elongated, narrow, greatly coiled tube, the first part of which or *duodenum* (*du* and *du*) forms a U-shaped loop. The large intestine is a wide tube, the first and greater part of which, termed the *colon*, has its walls sacculated, a structure which is absent in the short, straight posterior part or *rectum* (*rct*). At the junction of the small with the large intestine is a very wide blind tube, the *cæcum*, which is of considerable length and is marked by a spiral constriction, indicating the presence in its interior of a narrow spiral valve. At its extremity is a small, fleshy, finger-like *vermiform appendix*.

The intestine, like that of the pigeon, is attached throughout its length to the dorsal wall of the abdominal cavity by a *mesentery* or fold of the lining membrane or peritoneum.

The *liver* is attached to the diaphragm by a fold of the peritoneum. Its substance is partly divided by a series of fissures into five lobes. A thin-walled gall-bladder lies in a depression on its posterior surface. The common *bile duct*, (*c. b. d*) formed by the union of the *cystic duct* from the gall-bladder and *hepatic ducts* from the various parts of the liver, runs to open into the duodenum near the pylorus.

The *pancreas* (*pn*) is a diffused gland in the fold of mesentery passing across the loop of the duodenum. Its single duct, the *pancreatic duct* (*pn. d*), opens into the distal limb of the loop.

The *heart* (Fig. 306) is situated in the cavity of the thorax, a little to the left of the middle line, and lies between the two pleural sacs enclosing the lungs. The pericardial membrane enclosing the heart consists of two layers, a *parietal*, forming the wall of the pericardial cavity, and a

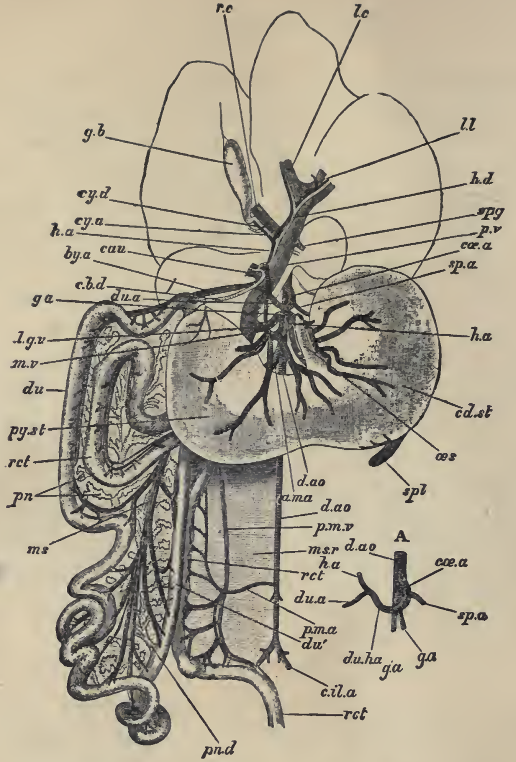

Fig. 305. — **Lepus cuniculus.** The stomach, duodenum, posterior portion of rectum and liver (in outline) with their arteries veins, and ducts. A. the cœliac artery of another specimen (both × ⅜). The gullet is cut through and the stomach somewhat displaced backwards to show the ramifications of the cœliac artery (*cœ. a*); the duodenum is spread out to the right of the subject to show the pancreas (*pn*); the branches of the bile duct (*c. b. d*), portal vein (*p. v*) and hepatic artery (*h. a*), are supposed to be traced some distance into the various lobes of the liver. *a. m. a*, anterior mesenteric artery; *cau*, caudate lobe of liver, with its artery, vein, and bile duct; *c. b. d*, common bile duct; *cd. st*, cardiac portion of stomach; *c. il. a*, common iliac artery; *cœ. a*, cœliac artery; *cy. a*, cystic artery; *cy. d*, cystic duct; *d. ao*, dorsal aorta; *du*, proximal, and *du'*, distal limbs of duodenum; *du. a*, duodenal artery; *du. ha*, in (A), duodeno-hepatic artery; *g. a*, gastric artery and vein; *g. b*, gall-bladder; *h. a*, hepatic artery; *b. d*, left bile duct; *l. c*, left central lobe of liver, with its artery, vein, and bile duct; *l. g. v*, lieno-gastric vein; *l. l*, left lateral lobe of liver, with its artery, vein, and bile duct; *ms*, branch of mesenteric artery and vein to duodenum; *ms. r*, mesorectum; *m. v*, chief mesenteric vein; *œs*, œsophagus; *p. m. a*, posterior mesenteric artery; *p m. v*, posterior mesenteric vein; *pn*, pancreas; *pn. d*, pancreatic duct; *p: v*, portal vein; *py. st*, pyloric portion of stomach; *rct*, rectum; *r c*, right central lobe of liver, with artery, vein, and bile duct; *spg*, Spigelian lobe of liver, with its artery, vein, and bile duct; *spl*, spleen; *sp. a*, splenic artery. (From Parker's *Zootomy*.)

visceral, immediately investing the heart. Between the two is a narrow cavity containing a little fluid, the *pericardial fluid.* In general shape the heart resembles that of the pigeon, with the apex directed backwards and slightly to the left, and the base forwards. Like that of the pigeon, it contains right and left auricles and right and left ventricles, the right and left sides of the heart having their cavities completely separated off from one another by inter-auricular and inter-ventricular partitions.

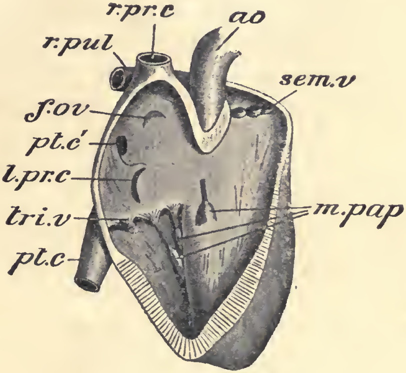

FIG. 306. — **Lepus cuniculus.** Heart, seen from the right side, the walls of the right auricle and right ventricle partly removed so as to expose the cavities. *ao*, aorta; *f. ov*, fossa ovalis; *l. pr. c*, opening of pre-caval; *m. pap*, musculi papillares; *pt. c*, post-caval; *pt. c'*, opening of post-caval; *r. prc*, right pre-caval; *r. pul*, right pulmonary artery; *sem. v*, semi-lunar valves; *tri*, tricuspid valve.

Into the right auricle open three large veins, the *right* and *left pre-caval* veins and the single *post-caval,* the first into the anterior part, the second into the left-hand side of the posterior portion, and the third into the dorsal surface. Projecting forwards from it is an ear-like *auricular appendix.* On the septum is an oval area where the partition is thinner than elsewhere; this is the *fossa ovalis*, it marks the position of an aperture, the *foramen ovale*, in the fœtus. The cavity of the right auricle communicates with that of the right ventricle by the wide right auriculo-ventricular opening. This is guarded by a valve, the *tricuspid*, composed of three membranous lobes or cusps, so arranged and attached that while they flap back against the walls of the ventricle to allow the passage of blood from the auricle to the ventricle, they meet together across the aperture so as to close the passage when the ventricle contracts. The lobes of the valve are attached to muscular processes of the wall of the ventricle, the *musculi papillares*, by means of tendinous threads called the *chordæ tendineæ*. The right ventricle, much thicker than the auricle, forms the right side of the conical apical portion, but does not extend quite to the apex. Its walls are raised up into muscular ridges called *columnæ carneæ*. It gives off in front, at its left anterior angle, the pulmonary artery, the entrance to which is guarded by three pouch-like *semi-lunar valves*.

The left auricle, like the right, is provided with an auricular appendix. Into this cavity on its dorsal aspect open together the right and left pulmonary veins. A large left auriculo-ventricular opening leads from the cavity of the left auricle into that of the left ventricle; this is guarded by a valve, the *mitral*, consisting of two membranous lobes or cusps with chordæ tendineæ and musculi papillares. In the walls of the ventricle are columnæ carneæ rather more strongly developed than in the right. At the basal (anterior) end of the left ventricle is the opening of the aorta, guarded by three semi-lunar valves similar to those at the entrance of the pulmonary artery. The *coronary* arteries, which supply the muscular substance of the heart,

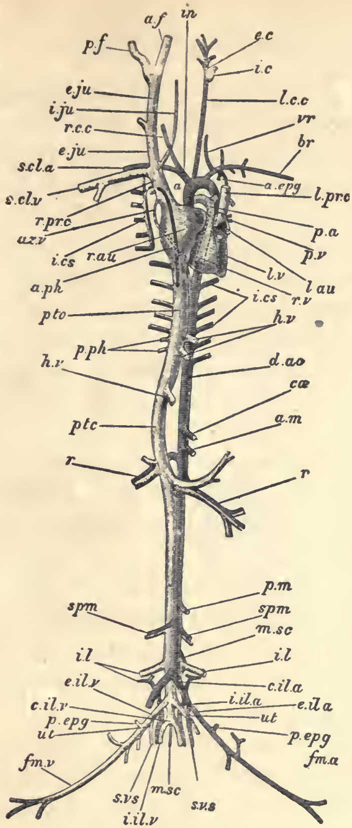
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FIG. 307. — **Lepus cuniculus**. The vascular system. The heart is somewhat displaced towards the left of the subject; the arteries of the right and the veins of the left side are in great measure removed. *a*, arch of the aorta; *a. epg*, internal mammary artery; *a. f*, anterior facial vein; *a. m*, anterior mesenteric artery; *a. ph*, anterior phrenic vein; *az. v*, azygos vein; *br*, branchial artery; *c. il. a*, common iliac artery; *cæ*, cœliac artery; *d. ao*, dorsal aorta; *e. c*, external carotid artery; *e. il. a*, external iliac artery; *e il. v*, external iliac vein; *e. ju*, external jugular vein; *fm. a*, femoral artery; *fm. v*, femoral vein; *h. v*, hepatic veins; *i. c*, internal carotid artery; *i. cs*, intercostal vessels; *i. ju*, internal jugular vein; *i l*, ilio-lumbar artery and vein; *in*, innominate artery; *l. au*, left auricle; *l. c. c*, left common carotid artery; *l. prc*, left pre-caval vein; *l. v*, left ventricle; *m. sc*, median sacral artery; *p. a*, pulmonary artery; *p. epg*, epigastric artery and vein; *p. f*, posterior facial vein; *p. m*, posterior mesenteric artery; *p. ph*, posterior phrenic veins; *ptc*, post-caval veins; *p. v*, pulmonary vein; *r*, renal artery and vein; *r. au*, right auricle; *r. c. c*, right common carotid artery; *r. prc*, right pre-caval vein; *r. v*, right ventricle; *scl. a*, right sub-clavian artery; *scl. v*, sub-clavian vein; *spm*, spermatic artery and vein; *vs. s*, superior vesical artery and vein; *ut*, uterine artery and vein; *vr*, vertebral artery. (From Parker's *Zootomy*.)

are given off from the aorta just beyond the semi-lunar valves. The corresponding vein opens into the terminal part of the left pre-caval. The pulmonary artery divides into two, a right and a left, each going to the corresponding lung.

The aorta gives origin to a system of arterial trunks by which the arterial blood is conveyed throughout the body. It first runs forwards from the base of the left ventricle, then bends round the left bronchus, forming the *arch* of the aorta (Fig. 307, *a*), to run backwards through the thorax and abdomen, in close contact with the spinal column, as the *dorsal aorta* (*d. ao*).

The system of *caval* veins which open into the right auricle consists of the *right* and *left pre-cavals* and of the single *post-caval*. From the liver the blood is carried to the post-caval by the *hepatic* veins.

The *hepatic portal system* consists, as in other vertebrates, of a series of veins conveying blood from the various parts of the alimentary canal to the liver, the trunks of the system uniting to form the single large *portal vein* (Fig. 307, *p. v*). There is no renal portal system.

Respiratory Organs.—The *larynx* (Fig. 308) is a chamber with walls supported by cartilage, lying below and somewhat behind the pharynx, with which it communicates through a slit-like aperture. It contains the vocal cords. Leading backwards from the larynx is the *trachea* or windpipe (Fig. 308, *tr*), a long tube, the wall of which is supported by cartilaginous rings which are incomplete dorsally. The trachea enters the cavity of the thorax and there divides into the two *bronchi*, one passing to the root of each lung.

The *lungs* (Fig. 304) are enclosed in the lateral parts of the cavity of the thorax. Each lung lies in a cavity lined by a membrane—the cavity of the *pleural sac* or *pleural* *membrane*. The right and left pleural sacs are separated by a considerable interval owing to the development in the partition between them of a space, the mediastinum, in which lie the heart and other organs. The lung is attached only at its root where the pleural membrane is reflected over it. In this respect it differs widely from the lung of the bird. It differs also in its minute structure. The bronchus entering at the root divides and subdivides to form a ramifying system of tubes, each of the ultimate branches of which, or *terminal bronchioles*, opens into a minute chamber or *infundibulum*, consisting of a central passage and a number of thin-walled *air-vesicles* or *alveoli* given off from it.

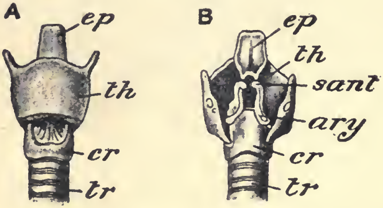

FIG. 308.—**Lepus cuniculus.** Larynx: A, ventral view; B, dorsal view; *ary*, arytenoid; *cr*, cricoid; *ep*, epiglottis; *sant*, cartilage of Santorini; *th*, thyroid, *tr*, trachea. (From Krause, after Schneider.)

The *spleen* is an elongated, compressed, dark red body situated in the abdominal cavity in close contact with the stomach, to which it is bound by a fold of the peritoneum. The *thymus*, much larger in the young rabbit than in the adult, is a soft mass, resembling fat in appearance, situated in the ventral division of the mediastinal space below the base of the heart. The *thyroid* is a small brownish, bilobed glandular body situated in close contact with the ventral surface of the larynx.

The neural cavity, as in the pigeon, contains the central organs of the cerebro-spinal nervous system, the *brain* and *spinal cord*. The brain (Fig. 309) of the rabbit contains the same principal parts as that of the pigeon, with certain differences, of which the following are the most important.

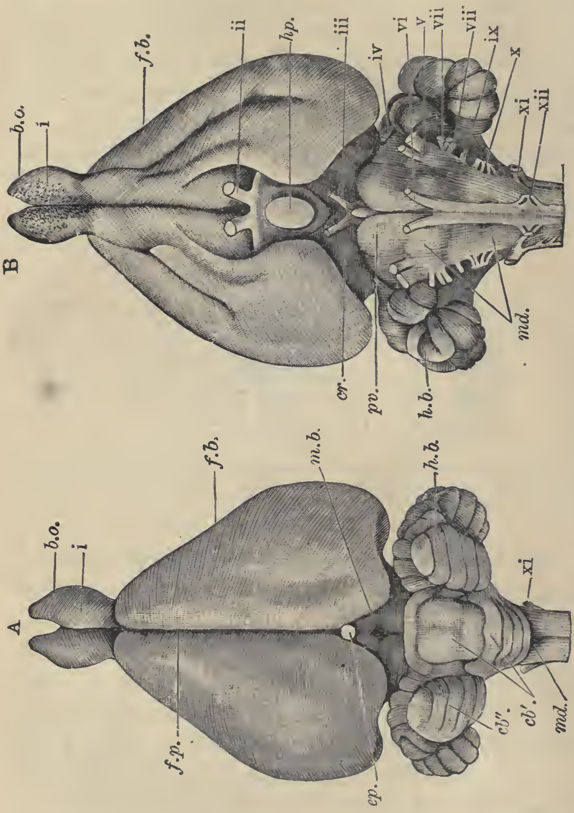

FIG. 309.—**Lepus cuniculus.** Brain. A, dorsal view; B, ventral. *b. o*, olfactory lobe; *cb'*, median lobe of cerebellum (vermis); *cb''*, lateral lobe of cerebellum; *cr*, cauro-cerebri; *ep*, epiphysis; *f. b*, parencephala; *f. p*, longitudinal fissure; *h. b*, hind-brain; *hp*, hypophysis; *m. b*, mid-brain (corpora quadrigemina); *md*, medulla oblongata; *p. v*, pons Varolii; i-xii, cranial nerves. (After Wiedersheim.)

The surface of the cerebral hemispheres (Fig. 309, *f. b*, Fig. 310, *c. h*), which are relatively long and narrow, presents certain depressions or sulci, which, though few and indistinctly marked, yet divide the surface into lobes or convolutions not distinguishable in the case of the pigeon or the lizard. A slight depression, the *Sylvian fissure*, at the side of the hemisphere separates off a lateral portion or *temporal lobe* (Fig. 311, *ch*^{2}) from the rest. There are very large club-shaped olfactory lobes at the anterior extremities of the cerebral hemispheres. Connecting together the two hemispheres is a commissural structure, the *corpus callosum* (Fig. 310, *cp. cl*), not present in the pigeon; this runs transversely above the level of the lateral ventricles. Below the corpus callosum is another characteristic structure of a commissural nature, the *fornix* (*b. fo*), a narrow median strand of longitudinal fibres which bifurcates both anteriorly and posteriorly. Below the corpus callosum, between it and the fornix, the thin inner walls of the hemispheres (*septum lucidum*) (*sp. lu.*) enclose a small, laterally compressed cavity, the so-called *fifth ventricle* or *pseudocœle;* this is not a true ventricle, but merely a space between the closely apposed hemispheres.

The lateral ventricles of the cerebral hemispheres are much more extensively developed than in the brain of the pigeon, and of somewhat complex shape.

The floor of the anterior portion of the lateral ventricle is formed of an eminence of gray matter, the *corpus striatum* (*cp. s*). The right and left corpora striata are connected together by a narrow transverse band of white fibres, the *anterior commissure* (*a. co*).

The diacœle (v^3) is a laterally compressed cavity. From the posterior part of the roof of the diacœle arises the peduncles of the pineal body, and just beyond their point of origin is the *posterior commissure* (*p. co*), a delicate transverse band of fibres connecting together the posterior parts of the *optic thalami*. The latter (*o. th*) are large

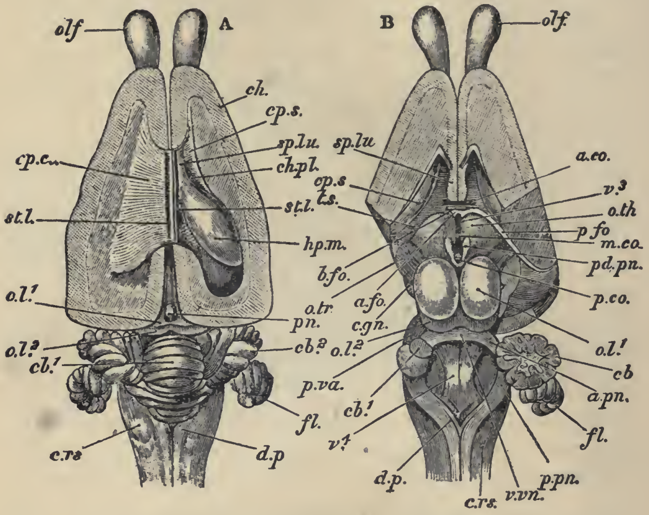

FIG. 310.—**Lepus cuniculus.** Two dissections of the brain from above (nat. size). In *A*, the left parencephalon is dissected down to the level of the corpus callosum; on the right the lateral ventricle is exposed. In *B*, the cerebral hemispheres are dissected to a little below the level of the anterior genu of the corpus callosum; only the frontal lobe of the left hemisphere is retained; of the right, a portion of the temporal lobe also is left; the velum interpositum and pineal body are removed, as well as the greater part of the body of the fornix, and the whole of the left posterior pillar; the cerebellum is removed with the exception of a part of its right lateral lobe; *a. co*, anterior commissure; *a. fo*, anterior pillar of fornix; *a. pn*, anterior peduncles of cerebellum; *b. fo*, body of fornix; cb^1, superior vermis of cerebellum; cb^2, its lateral lobe; *c. gn*, corpus geniculatum; *c. h*, cerebral hemisphere; *ch. pl*, choroid plexus; *cp. cl*, corpus callosum; *cp. s*, corpus striatum; *c. rs*, corpus restiforme; *d. p*, dorsal pyramid; *fl*, flocculus; *hp. m*, hippocampus major; *m. co*, middle commissure; $o.\ l^1$, anterior; $o\ l^2$, posterior lobes of corpora quadrigemina; *o. th*, optic thalamus; *otr*, optic tract; *p. co*, posterior commissure; *p fo*, posterior peduncles of cerebellum; *p. va*, fibres of pons Varolii forming middle peduncles of cerebellum; *sp. lu*, septum lucidum; *st l*, stria longitudinalis; *t. s*, tœnia semicircularis; *v. vn*, valve of Vieussens; v^3, third ventricle; v^4, fourth ventricle. (From Parker's *Zootomy*.)

masses of mixed gray and white matter forming the lateral portions of the diencephalon; they are connected together by a thick mass of gray matter, the *middle* or *soft commissure* (*m. co*) passing across the diacœle. The floor of the diencephalon is produced downwards into a mesial rounded process, the *tuber cinereum* or *infundibulum* (*inf*) to which the pituitary body is attached. In front of this, on the ventral aspect of the brain, is a thick curved transverse band of nerve fibres, the united *optic tracts*, from the anterior border of which the optic nerves are given off. Behind the tuber cinereum is a rounded elevation, the *corpus mammillare* (*c. ma*).

In the mid-brain the dorsal part is remarkable for the fact that each *optic lobe* is divided into two by a transverse furrow, so that two pairs of lobes, the *corpora quadrigemina*, are produced. On the ventral region of the mid-brain the *crura cerebri* are far more prominent than in the lower groups. In the hind-brain the *cerebellum* (Fig. 310, *cb'*, *cb''*) is very large; it consists of a *central lobe* or *vermis* and two *lateral lobes* divided by very numerous fissures or sulci into a large number of small convolutions. Each lateral lobe bears an irregularly shaped prominence, the flocculus. On section (Fig. 311, *cb*) the cerebellum exhibits a tree-like pattern (*arbor vitæ*), brought about by the arrangement of the white and gray matter. On the ventral aspect of the hind-brain a flat band of transverse fibres, the *pons Varolii*, connects together the lateral parts of the cerebellum.

The cranial nerves are similar to those of the pigeon in most respects, differing in some of the particulars of their arrangement and distribution.

The rabbit, like most other vertebrates, possesses a *sympathetic nervous system*, consisting of a series of ganglia united together by commissural nerves and giving off branches to the various internal organs.

In the **organs of special sense** the following special features are to be seen when a comparison is made with the pigeon. In the eye, the sclerotic is composed entirely of dense fibrous tissue; the pecten is absent. In the ear the principal point of difference is in the special development of the *cochlea*. This part of the membranous labyrinth, instead of retaining the simple curved form which it presents in the bird, is coiled on itself in a close spiral of two and a half turns.

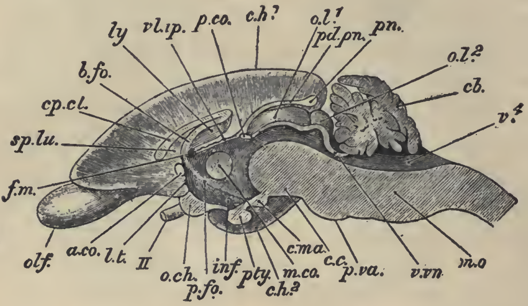

FIG. 311.—**Lepus cuniculus.** Longitudinal vertical section of the brain (nat. size). Letters as in the preceding figure; in addition, *cb*, cerebellum, showing arbor vitæ; *c. c*, crus cerebri; *ch*¹, parencephalon; *ch*², temporal lobe; *c. ma*, corpus mammillare; *f. m*, foramen of Monro; *inf*, infundibulum; *ly*, lyra; *m. o*, medulla oblongata; *o. ch*, optic chiasma; *olf*, olfactory lobe; *pty*, pituitary body; *vl. ip*, velum interpositum; *v. vn*, valve of Vieussens; *II*, optic nerve. (From Parker's *Zootomy*.)

The special features of the middle ear with its auditory ossicles have been already referred to.

The kidneys are of somewhat compressed oval shape, with a notch or *hilus* on the inner side. They are in close contact with the dorsal wall of the abdominal cavity, the right being somewhat in advance of the left. Towards the hilus the tubules of the kidney converge to open into a wide chamber, the *pelvis*, which forms the dilated commencement of the ureter. When the kidney is cut across, its substance is seen to be divided into a central mass or *medulla* and a peripheral portion or *cortex*. An *adrenal* (*suprarenal*) *body* lies in contact with the anterior end of each kidney. The *ureter* (Fig. 312, *ur*) runs backwards to open not into a cloaca but directly into the *urinary bladder* (*bl*). The latter is a pyriform sac with elastic walls which vary in thickness according as the organ is

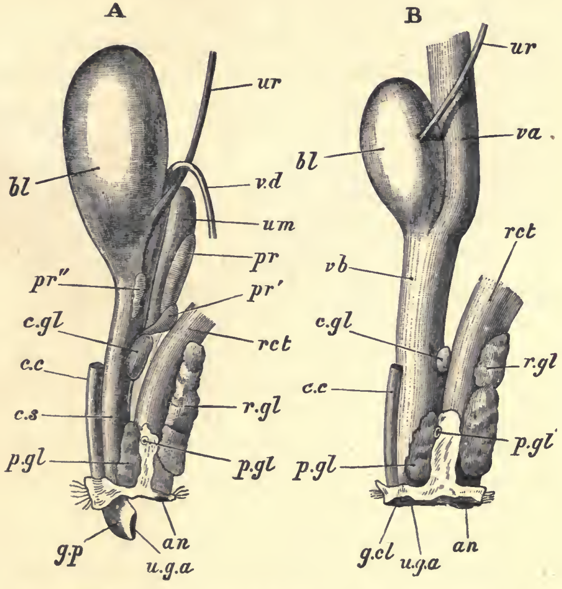

FIG. 312.—**Lepus cuniculus.** The urogenital organs. A, of male; B, of female, from the left side (half nat. size). The kidneys and proximal ends of the ureters, and in B, the ovaries, Fallopian tubes and uteri are not shown. *an*, anus; *bl*, urinary bladder; *c. c*, corpus cavernosum; *c. s*, corpus spongiosum; *c. gl*, Cowper's gland; *g. cl*, glans clitoridis; *g. p*, glans penis; *p. gl*, perineal gland; *p. gl′*, aperture of its duct on the perineal space; *pr*, anterior, *pr′*, posterior, and *pr″*, lateral lobes of prostate; *rct*, rectum; *r. gl*, rectal gland; *u. g. a*, urinogenital aperture; *u. m*, uterus masculinus; *ur*, ureter; *va*, vagina; *vb*, vestibule; *v. d*, vas deferens. (From Parker's *Zootomy*.)

dilated or contracted. In the male the openings of the ureters are situated much nearer the posterior narrower end or neck than in the female.

In the male rabbit the *testes* are oval bodies, which, though in the young animal they occupy a similar position to that which they retain throughout life in the pigeon, pass backwards and downwards as the animal approaches maturity until they come to lie each in a *scrotal sac* situated at the side of the urogenital opening. The cavity of each scrotal sac is in free communication with the cavity of the abdomen by an opening, the *inguinal canal.* A convoluted *epididymis*, closely adherent to the testis, forms the proximal part of the *vas deferens.* The *vasa deferentia* (*vd*) terminate by opening into a urogenital canal, or *urethra*, into which the neck of the urinary bladder is continued. A *prostate gland* (*pr*) surrounds the commencement of the urethra, the neck of the bladder, and the terminal parts of the vasa deferentia. A diverticulum of the urethra, the *uterus masculinus* (*um*), lies embedded in the prostate gland close to the neck of the bladder. A small pair of ovoid glands, *Cowper's glands* (*c. gl*), lie just behind the prostate close to the side of the urethra.

The terminal part of the urethra traverses a cord of vascular tissue, the *corpus spongiosum* (*c. s*), which forms the dorsal portion of the penis. A loose fold of skin, the *prepuce*, encloses the penis.

In the female the *ovaries* are small ovoid bodies attached to the dorsal wall of the abdomen behind the kidneys. The *Graafian follicles* enclosing the ova form only very small rounded projections on their outer surface.

The *oviducts* in the anterior part of their extent (*Fallopian tubes*) are very narrow and slightly convoluted. They open into the abdominal cavity by wide funnel-shaped openings, with fimbriated or fringed margins. Posteriorly each passes into a thick-walled *uterus*. The two uteri open separately into a median tube, the *vagina* (*va*). The *vestibule* (Fig. 312, *vb*), or urogenital canal, is a wide median passage, into which the vagina and the bladder open. On its ventral wall is a small, hard, rod-like body, the *clitoris*, corresponding to the penis of the male, and composed of two very short *corpora cavernosa* attached anteriorly to the ischia, with a terminal soft conical *glans clitoridis* (*g. cl*). The *vulva*, or external opening of the vestibule, is bounded laterally by two prominent folds, the *labia majora*.

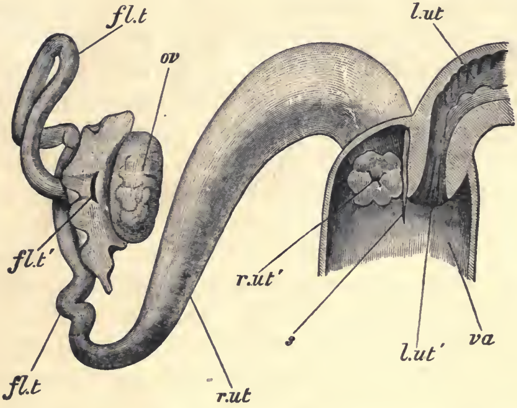

FIG. 313. — **Lepus cuniculus**. The anterior end of the vagina, with the right uterus, Fallopian tube, and ovary (nat. size). Part of the ventral wall of the vagina is removed, and the proximal end of the left uterus is shown in longitudinal section *fl. t*, Fallopian tube; *fl. t'*, its peritoneal aperture; *l. ut*, left uterus; *l. ut'*, left os uteri; *r. ut*, right uterus; *r. ut'*, right os uteri; *s*, vaginal septum; *va*, vagina. (From Parker's *Zootomy*.)

The rabbit is viviparous. The ovum, which is of relatively small size, after it has escaped from its Graafian follicle, passes into the oviduct, where it becomes fertilised, and reaches the uterus, in which it develops into the *fœtus*, as the intra-uterine embryo is termed. The young animal escapes from the uterus in a condition in which all the parts have become fully formed, except that the eyelids are still closed, and the hairy covering is not yet completed. As many as eight or ten young are produced at a birth, and the period of gestation, *i.e.*, the time elapsing between the fertilisation of the ovum and the birth of the young animals is thirty days. Fresh broods may be born once a month throughout a considerable part of the year, and, as the young rabbit may begin breeding at the age of three months, the rate of increase is very rapid.

During intra-uterine life the young rabbit is nourished by an organ called the *placenta*, formed by an intimate union between certain structures, the fœtal membranes, derived from the embryo, and a specially modified part of the wall of the uterus. By means of the placenta a close connection is established between the blood-system of the fœtus and that of the parent, and nourishment is thus received by the former from the latter.

After birth the young rabbits are nourished for a time wholly by the milk or secretion of the mammary glands of the mother.

The following are the principal general features which characterise the **Mammalia** as a class:—

The Mammalia are air-breathing vertebrates, with warm blood, and with an epidermal covering in the form of hairs. The bodies of the vertebræ are in nearly all mammals ossified each from three independent centres, one of which develops into the centrum proper, while the others give rise to thin discs of bone, the epiphyses. Also characteristic of the spinal column of mammals are the discs of fibro-cartilage termed inter-vertebral discs, which intervene between successive centra.

The skull has two condyles in connection with the atlas, instead of the single condyle of the reptiles and birds; and the lower jaw articulates with the skull in the squamosal region without the intermediation of the separate quadrate element always present in that position in birds and reptiles. Each of the long bones of the limbs is composed in the young condition of a central part or shaft and terminal epiphyses, the latter only becoming completely united with the shaft at an advanced stage. In the pectoral arch the coracoid of the birds and reptiles is usually represented only by vestiges, which unite with the scapula in the adult.

Mammals are typically *diphyodont*, *i.e.*, have two sets of teeth — a milk or deciduous set, and a permanent set; some are *monophyodont*, *i.e.*, have only one set. The teeth are *thecodont*, *i.e.*, the base of each tooth is embedded in a distinct socket or alveolus in the substance of the bone of the jaw; and nearly always the teeth in different parts of the jaw are clearly distinguishable by differences of shape into incisors, canines, and grinding teeth, *i.e.*, are *heterodont;* in some instances the teeth are all alike (*homodont*). A cloaca is absent except in the Prototheria.

A movable plate of cartilage, the epiglottis, overhangs the glottis or passage leading from the pharynx into the cavity of the larynx.

A partition of muscular fibres, usually with a tendinous centre, the diaphragm, divides the cavity of the body into two parts, — an anterior, the thorax, containing the heart and lungs, and a posterior, the abdomen, containing the greater part of the alimentary canal with its associated glands, the liver and pancreas, and the renal and reproductive organs.

The lungs are freely suspended within the cavity of the thorax. The heart is completely divided into two halves, a right and a left, between which there is no aperture of communication. Each half consists of an auricle and a ventricle, opening into one another by a wide opening, guarded by a valve composed of three membranous cusps on the right side, two on the left. The right ventricle gives off the pulmonary artery; the left gives off the single aortic arch, which passes over to the left side, turning round the left bronchus in order to run backwards as the dorsal aorta. The blood is warm. The red blood-corpuscles are non-nucleated and usually circular.

The two cerebral hemispheres, in all but the monotremes and marsupials, are connected together by a band of transverse fibres, the corpus callosum, not represented in the lower vertebrates. The dorsal part of the mid-brain is divided into four optic lobes, the corpora quadrigemina. On the ventral side of the hind-brain is a transverse band of fibres, the pons Varolii, by which the lateral portions of the cerebellum are connected together.

The ureters, except in the Prototheria, open into the bladder.

Mammals are all, with the exception of the monotremes, viviparous. The fœtus is nourished before birth from the blood-system of the parent through a special development of the fœtal membranes and the lining membrane of the uterus, termed the placenta. After birth the young mammal is nourished for a longer or shorter time by the milk or secretion of the mammary glands of the parent.

The class Mammalia is divisible into two main divisions or sub-classes, the **Prototheria** and the **Theria**.

The **Prototheria** are mammals in which the mammary glands are devoid of teats; the oviducts are distinct throughout, and there is a cloaca into which the ureters and the urinary bladder open separately. In the centra of the vertebræ the epiphyses are absent or more imperfectly developed; the bones of the skull early coalesce by the obliteration of the sutures; there is a large coracoid articulating with the sternum, and a T-shaped episternum, and there is a pair of epipubic (marsupial) bones. In the brain a corpus callosum is absent. The ova are discharged in an early stage of their development, enclosed in a tough shell.

This sub-class comprises a single living order, the Monotremata, including the duck-bill or Platypus (*Ornithorhynchus*) and spiny ant-eater (*Echidna*).

The **Theria** are mammals in which the mammary glands are provided with teats; the oviducts are united in a longer or shorter part of their extent, and there is no cloaca, the ureters opening into the base of the bladder. The centra of the vertebræ possess distinct epiphyses; the bones of the skull in most instances do not completely coalesce, most of the sutures remaining distinguishable throughout life; the coracord is represented by vestiges, and an episternum is absent as a distinct bone. The early development of the young takes place in the uterus.

Of the Theria again there are two sections, the Metatheria or Marsupialia and the Eutheria.

The section Metatheria comprises all the pouch-bearing mammals or marsupials, such as the opossums, the dasyures, the bandicoots, the wombats, the phalangers, and the kangaroo, nearly all, with the exception of the opossums, confined to the Australian region. They are characterised by the possession of a pouch or *marsupium*, within which the young, born in rudimentary and helpless condition, are sheltered. They also possess a pair of peculiar bones, the *epipubic* or *marsupial* bones (present also in the Prototheria), attached to the pubes.

In the **Eutheria** marsupium and marsupial bones are absent. This section comprises the great majority of mammals, which, when the fossil forms are left out of account, are capable of being arranged in nine orders: —

1. *Edentata*, comprising the sloths, ant-eaters, and armadillos.

2. *Cetacea*, including the whales, porpoises, and dolphins.

3. *Sirenia*, or dugongs and manatees.

4. *Ungulata*, a very large order, comprising among others, the horses, tapirs, and rhinoceroses, the ruminants (camels, oxen, sheep, goats, antelopes, giraffes, and deer), the pigs and hippopotami, the hyraxes, and the elephants.

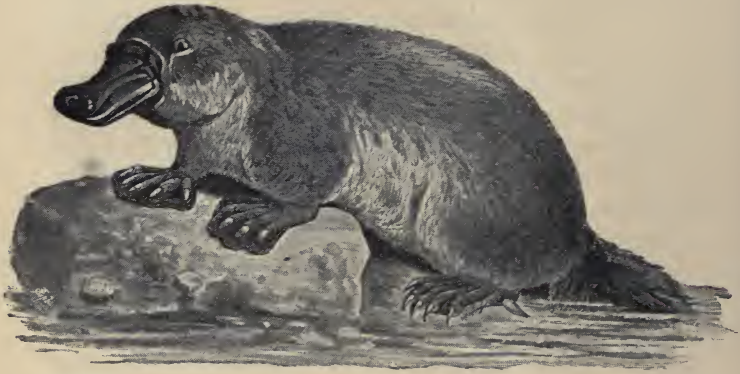

FIG. 314. — **Duck-bill** (*Ornithorhynchus anatinus*). (After Vogt and Specht.)

5. *Carnivora*, or the cats, dogs, bears, weasels, and otters, and the seals and walruses.

6. *Rodentia*, a large order, including, among many others, the rats and mice, hares and rabbits, squirrels, beavers, and porcupines.

7. *Insectivora*, including the moles, shrews, and hedgehogs.

8. *Chiroptera*, or bats, and fruit-eating bats (flying foxes).

9. *Primates*, comprising the lemurs, apes, and monkeys, and the human species.

The two genera of the Prototheria, *Ornithorhynchus* and *Echidna*, differ somewhat widely from one another in general appearance. The former (Fig. 314) has the surface covered with a close soft fur, and has the upper jaw produced into a depressed muzzle, not unlike the beak of a duck, covered with a smooth, hairless integument. The eyes are very small, and there is no auditory pinna. The legs are short, and the five digits end in strong claws, and are connected together by a web, so that the limbs are equally adapted for burrowing and for swimming. The tail is elongated and depressed, covered with fur. The male has a sharp-pointed, curved spur on the inner side of the foot, having the duct of a poison-gland opening at its apex. Echidna (Fig. 315) has the body covered above with strong-pointed spines, between which are coarse hairs; the

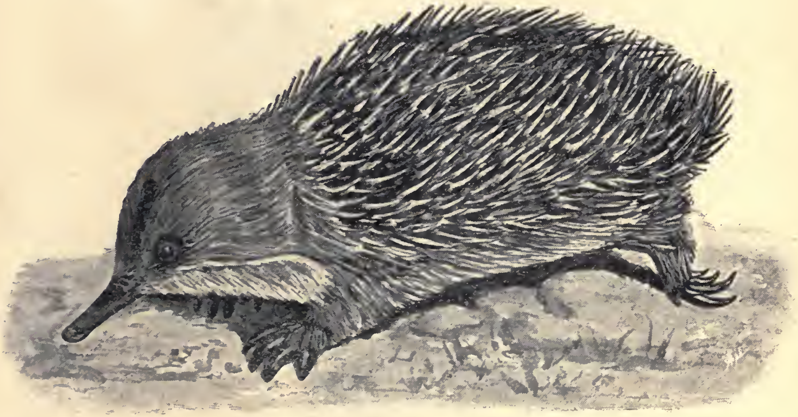

FIG. 315.—**Spiny Ant-eater** (*Echidna aculeata*). (After Vogt and Specht.)

lower surface is covered with hair only. The jaws are produced into a rostrum which is much narrower than that of Ornithorhynchus. The eyes are small, and there is no auditory pinna. The tail is vestigial.

The opossums (*Didelphyidæ*) (Fig. 316) are arboreal rat-like marsupials, with elongated naked muzzle, with well-developed, though nailless, opposable hallux, and elongated prehensile tail. The Dasyuridæ (Australian native cats, tasmanian devil, thylacine, etc.) have the pollex often rudimentary, the foot four-toed, the hallux, when present, small and clawless, and the tail not prehensile.

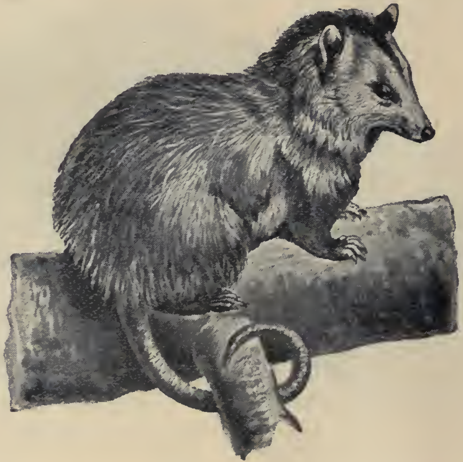

Fig. 316. — Virginian Opossum (*Didelphys virginiana*). (After Vogt and Specht.)

The bandicoots (*Peramelidæ*) are burrowing marsupials, the size of which varies from that of a large rat to that of a rabbit. They have an elongated pointed muzzle, and, in some cases, large auditory pinnæ. The first and fifth digits of the fore-foot are vestigial or absent, the remaining three nearly equally developed. In the hind-foot the fourth toe is much longer and stouter than the others, while the second and third are small and slender, and united together by a web of skin, and the first is vestigial or absent. The marsupium has its opening directly backwards.

The wombats (*Phascolomyidæ*) are large, heavy, thick-bodied, burrowing animals, with short flattened heads, short thick limbs, provided with strong claws on all the digits except the hallux, and with the second, third, and fourth of the hind-foot partly connected together by skin. The tail is very short. The kangaroos and their allies (*Macropodidæ*) (Fig. 318) are adapted, as regards their limbs, for swift terrestrial locomotion. They have a relatively small head and neck, the fore-limbs small, and each provided with five digits; the hind-legs long and powerful; rapid progression is effected by great springing leaps, with the body inclined forwards and the fore-limbs clear of the ground. The foot is narrow and provided with four toes, the hallux being absent; the two inner (second and third) small and

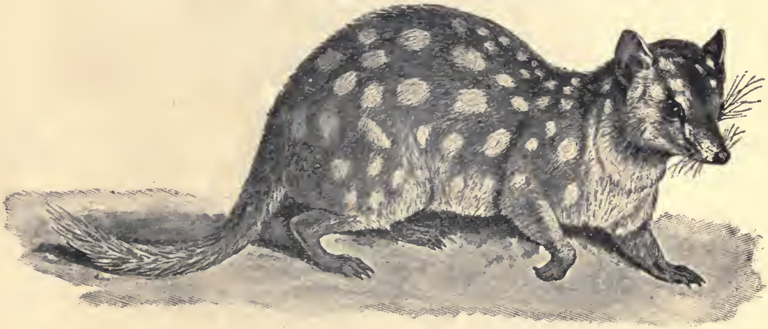

FIG. 317.—**Dasyure** (*Dasyurus viverrinus*). (After Vogt and Specht.)

united together by integument, while the middle one is very long and powerful. The tail is very long, and usually thick. There is a large marsupium.

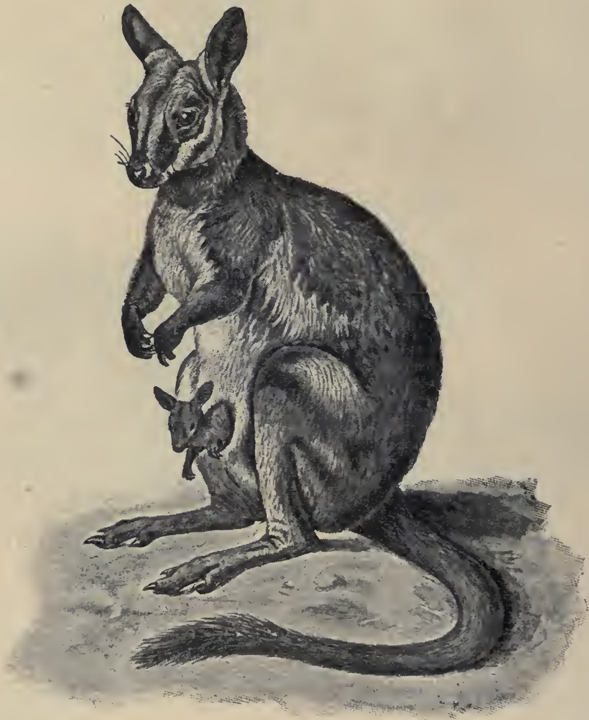

FIG. 318. — **Rock wallaby** (*Petrogale xanthopus*). (After Vogt and Specht.)

The Phalangers (*Phalangeridæ*) are climbing Marsupials which have both fore- and hind-feet prehensile ; the second and third toes of the hind-foot slender and united by a web, as in the kangaroo, but the hallux, which is nailless, opposable to them; the fourth and fifth nearly equal; the tail is well developed and prehensile. The koalas (Fig. 319) differ from the phalangers mainly in the relatively thicker body and the vestigial tail.

The sloths (*Bradypodidæ*) (Fig. 320) are more completely adapted, in the structure of their limbs, to an arboreal life than any other group of the Mammalia. They have a short, rounded head, with small pinnæ and long slender limbs, the anterior much longer than the posterior, with the digits, which are never more than three in number, long, curved, and hook-like, adapted for enabling the animal to hang and climb, body downwards, among the branches of trees. The tail is rudimentary. The body is covered with coarse hairs.

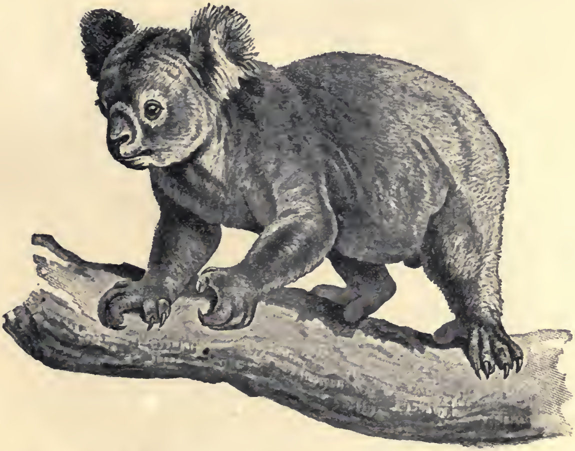

FIG. 319.—**Koala** (*Phascolarctos cinereus*). (After Vogt and Specht.)

The ordinary ant-eaters (*Myrmecophaga*) have a greatly elongated snout, with the mouth as a small aperture at its extremity, small eyes, and the auditory pinna sometimes small, sometimes well developed. There are five digits in the fore-foot, of which the third has always a very large, curved, and pointed claw, rendering the manus an efficient burrowing organ. The toes of the hind-foot, four or five in number, are sub-equal and provided with moderate-sized

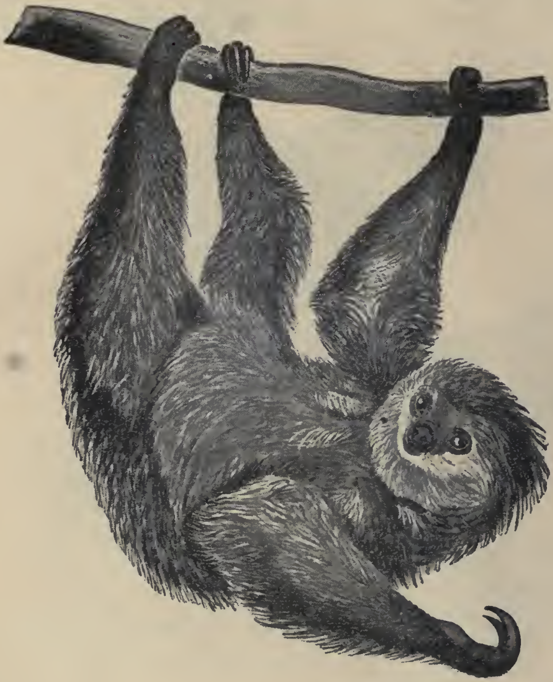

FIG. 320.—**Unau, or two-toed sloth** (*Cholœpus didactylus*).
(After Vogt and Specht.)

claws. The tail is always very long, and is sometimes prehensile. The body is covered with long hair.

In the armadillos (*Dasypodidæ*) (Fig. 321) the head is comparatively short, broad, and depressed. The number of complete digits of the fore-foot varies from three to five; these are provided with powerful claws, so as to form a very efficient burrowing organ. The hind-foot always has five digits with smaller claws. The tail is usually well developed.

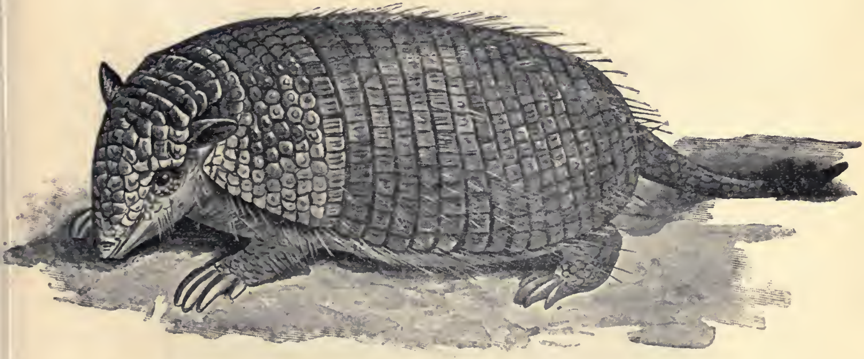

FIG. 321. — **Tatu armadillo** (*Dasypus sexcinctus*). (After Vogt and Specht.)

The most striking external feature of the armadillos is the presence of an armour of bony dermal plates. This usually consists of a scapular shield of closely united plates covering the anterior part of the body, followed by a series of transverse bands separated from one another by hairy skin, and a posterior pelvic shield. The tail is also usually enclosed in rings of bony plates, and a number protect the upper surface of the head. Dasypus occurs in southwestern Texas.

In the scaly ant-eaters (*Manis*) (Fig. 322) the head is produced into a short pointed muzzle. The limbs are short

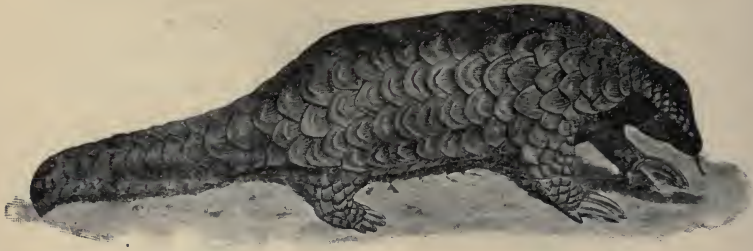

FIG. 322 — **Scaly ant-eater** (*Manis pentadactyla*). (After Vogt and Specht.)

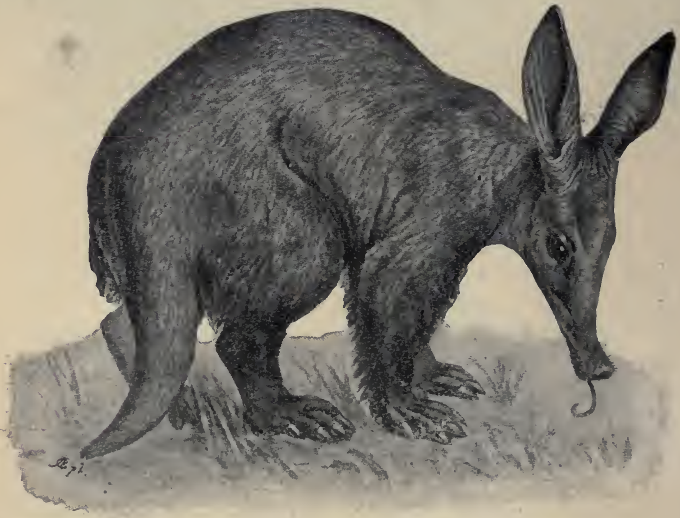

FIG. 323. — **Aard-vark** (*Orycteropus capensis*). (After Vogt and Specht.)

and strong, with five digits in each foot. The upper surface of the head and body, the sides of the latter, and the entire surface of the tail are covered with an investment of rounded horny epidermal scales. The lower surface is covered with hair, and there are a few coarse hairs between the scales. There are five digits in both manus and pes.

The aard-varks (Fig. 323) have a thick-set body, the head produced into a long muzzle with a small tubular mouth, the pinnæ of great length, the tail long and thick. The fore-limbs are short and stout, with four toes. The hind-limb is five-toed. The surface is covered with thick skin with sparse hairs.

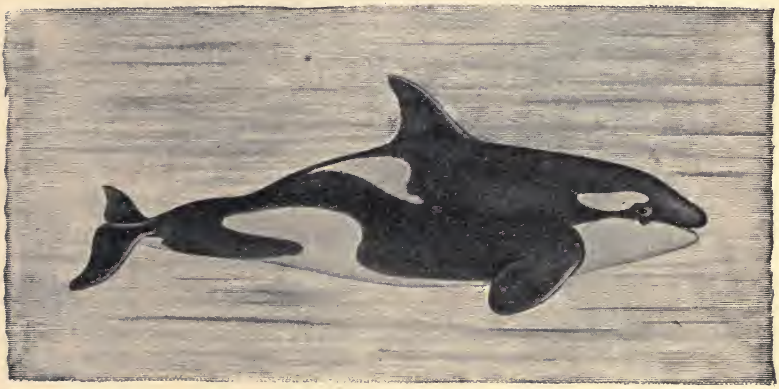

FIG. 324.—**Killer** (*Orca gladiator*). (After True.)

The Cetacea (Fig. 324), among which are the largest of existing mammals, are characterised by the possession of a fusiform fish-like body, tapering backwards to the tail, which is provided with a horizontally expanded caudal fin divided into two lobes or "flukes," and a relatively large head, not separated from the body by any distinct neck. A dorsal median fin is usually present. The fore-limbs take the form of flippers, with the digits covered over by a common integument and devoid of claws; the hind-limbs are absent. The mouth is very wide; the nostrils are situated on the summit of the head, and the auditory pinna is absent. Hairs are completely absent, or are represented only by a few bristles about the mouth. In the whale-bone whales (Fig. 325) the nostrils have two external slit-like apertures; in the toothed whales, porpoises, and dolphins, on the other hand, the two nostrils unite to open by a single crescentic valvular aperture.

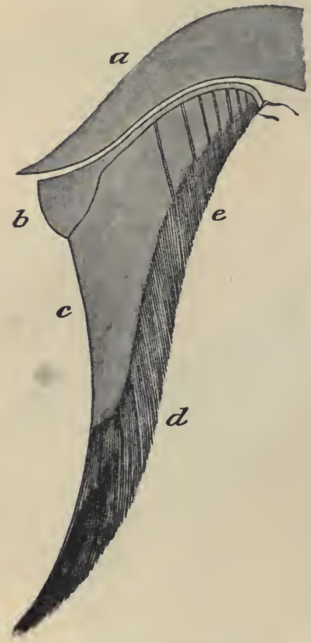

FIG. 325.—Section of upper jaw, with baleen-plates, of *Balænoptera*. (After Owen.)

In the Sirenia also the body is fish-like, with a horizontal caudal fin, the fore-limbs flipper-like, the hind-limbs absent, and the integument almost hairless. But the body is distinctly depressed, and the head is by no means so large in proportion as in the Cetacea, and has a tumid truncated muzzle, not far back from the extremity of which the nostrils are situated. There is no dorsal fin.

In the Ungulata vera the claws or nails of other mammals are replaced by thick solid masses, the *hoofs*, investing the ungual phalanges and bearing the weight of the body. The number of digits is more or less reduced, and the limbs as a whole are usually specially modified to act as organs of swift locomotion over the surface of the ground, their movements being restricted by the nature of the articulations to antero-posterior movements of flexion and extension. The metacarpal and metatarsal regions are relatively very long. In the sub-order Artiodactyla (or cattle, sheep, antelopes, giraffes, deer, camels, pigs, and hippopotami) the third and fourth digits of each foot form a symmetrical pair, and in the majority are the only digits that are completely developed. Characteristic of the ruminants are the cephalic appendages known as *horns* and *antlers*. The horns of the oxen, sheep, goats, and antelopes, sometimes developed in both sexes, sometimes only in the males, are horny sheaths supported on bony cores, which are outgrowths of the frontal bones. In the giraffes the horns, which are short and occur in both sexes, are bony structures covered with soft skin, and not at first attached by bony union to the skull, though subsequently becoming firmly fixed. The antlers of the deer, which, except in the case of the reindeer, are restricted to the male sex, are bony growths enclosed only while immature in a layer of skin, the "velvet," covered with very soft short fur. Antlers are shed annually, and renewed by the growth of fresh vascular bony tissue from the summit of a pair of short processes of the frontal bones, the *pedicles*.

In the pigs the legs are relatively short, and the two lateral toes of both manus and pes are fully developed, though scarcely reaching the ground. The surface is covered with a scanty coat of coarse bristles. There is a truncate mobile snout, the anterior end of which is disc-shaped and free from hairs. A remarkable feature of the males is the development of the canine teeth of both jaws into large, upwardly curved tusks.

In the hippopotami the body is of great bulk, the limbs very short and thick, the head enormous, with a transversely expanded snout, prominent eyes, and small pinnæ. The tail is short and laterally compressed. The toes are four in each manus and pes, all reaching the ground. The surface is naked, with only a few hairs in certain positions; the skin is of great thickness.

In the sub-order Perissodactyla (horses, tapirs, rhinoceroses) the third digit is either the only complete one in both fore- and hind-foot (horses) or there are only three digits, second, third, and fourth in each (rhinoceroses), or there are four in the fore-foot and three in the hind (tapirs). The horses (*Equidæ*) have the distal divisions of the limbs slender, the metacarpals and metatarsals nearly vertical to the surface of the ground, the single hoof massive and with a broad lower surface. Though the head is elongated, the nasal region is not produced into a proboscis. The tail is short or moderately long, and is either beset throughout with a large number of very long coarse hairs, or with a tuft of such specially developed hairs at the extremity. A mane of similar large hairs usually runs along the dorsal surface of the neck. There is a wart-like callosity above the wrist, and in the true horses a second a little below the heel or "hock."

The tapirs have the body more massive than the horses, and the limbs, especially the distal segments, shorter and stouter. The nasal region is produced into a short proboscis. The surface is beset with a scanty covering of hairs. The tail is vestigial.

In the rhinoceroses the body is extremely massive, the limbs short and stout, each digit provided with a hoof-like nail. There is a short soft muzzle. Either one or two remarkable median horns are borne on the nasal region, not attached directly to the skull; these are epidermal structures which are formed of a dense aggregation of slender fibre-like elements. The eyes are small, the auditory pinna well developed. The surface is devoid, or nearly devoid, of hairs, and the skin is enormously thick, and in some species thrown into deep folds. The tail is narrow and of moderate length.

The hyraxes are small, somewhat rabbit-like animals, with slender limbs and vestigial tail. There are four functional digits in the manus and three in the pes, all provided with short flat nails, except the innermost of the pes, which has a curved claw. The body is covered with soft fur.

The elephants, the largest of existing terrestrial mammals, have the limbs much more typically developed than in the true Ungulates, there being five comparatively short digits, enclosed in a common integument, in each foot, all of them in the fore-, and three or four in the hind-foot terminating in a broad flat nail. The limbs are very stout and pillar-like, and the thigh and leg when at rest are in a straight line instead of being, as in the Ungulata vera, placed nearly at right angles to one another — a circumstance which gives a characteristic appearance to the hind-quarters. The nasal region is produced into a proboscis or "trunk," a mobile cylindrical appendage, longer than the rest of the head, at the extremity of which the nostrils are situated. There is in the male a pair of enormous tusks, the incisors of the upper jaw. The eyes are small, the pinna of the ear enormous. The tail is small. The skin is very thick and provided with only a scanty hairy covering.

In the Carnivora the typical number of digits is sometimes present, or, more usually, there are five in the fore- and four in the hind-foot, or four in both. The extremities of the digits are provided with compressed curved claws, which may be very long and sharp, when they are capable, when not in use, of being retracted into a sheath of skin situated at their bases; or relatively short and blunt, when they are incompletely or not at all retractile. The otters (*Lutra*) differ from the rest in having short limbs with the toes connected by webs of skin.

The Pinnipedia, or seals and walruses (Fig. 326), have the proximal segments of the limbs short, so that the arm and thigh and nearly all the fore-arm and leg are enclosed in the common integument of the trunk, and the manus and pes elongated. The earless seals (*Phocidæ*) are much more completely adapted to an aquatic life than the eared seals (*Otariidæ*) and walruses (*Trichechidæ*), being unable to flex the thigh forwards under the body, so that the hind-limbs may aid in supporting the weight, and thus being only able to drag themselves along very awkwardly when on dry land. The pinna of the ear is absent in the earless seals and walruses, well developed in the eared seals. The surface in all is covered with a thick soft fur. In the fur seals there are two kinds of hairs, those of the one kind being longer and coarser and scattered through the more numerous shorter and finer hairs composing the fur proper. A remarkable

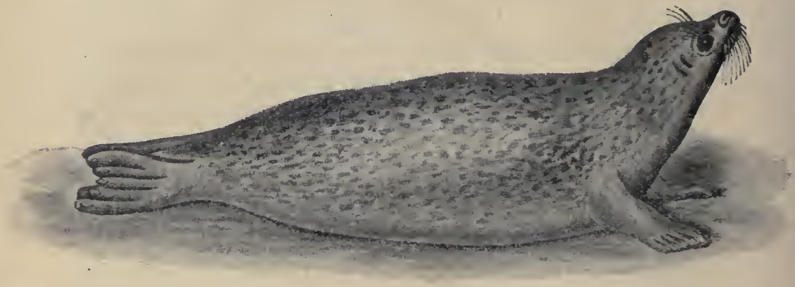

FIG. 326.—**Harbor Seal** (*Phoca vitulina*).

feature of the walruses is the presence of a pair of large tusks, the enlarged canine teeth, projecting downwards from the upper jaw.

Though some of the rodents (beavers, water voles) are aquatic, some (squirrels and tree-porcupines) are arboreal, while others (the majority of the order) lead a terrestrial life and are active burrowers; they are on the whole a very uniform group, and exhibit few such remarkable modifications as are to be observed in some of the other orders of mammals. They are nearly all furry animals with five-toed, plantigrade, or semi-plantigrade limbs. The tail is usually elongated, and may be naked or covered with fur; but sometimes, as in the rabbits and hares, it is very short. A few special modifications, however, have to be noted in certain families of rodents. The flying squirrels have on each side a fold of skin, the patagium, which serves as a parachute. The African flying squirrels (*Anomalurus*) are remarkable also on account of the presence of a series of overlapping horny scales on the lower surface of the basal part of the tail. The Jerboas (*Dipus*) and their allies are characterised by the great relative length of the hind-limbs — the mode of locomotion of these remarkable rodents being by a series of leaps not unlike the mode of progression of the kangaroo — and by the reduction of the number of the toes to three in some of them. The porcupines (*Hystricidæ*) have numerous elongated spines or "quills" among the hairs of the dorsal surface, and some of them have prehensile tails.

The Insectivora are, in general, small, furry, burrowing mammals with plantigrade limbs and an elongated muzzle. But there is a considerable range of modification within the order in adaptation to different modes of life. The cobegos (*Galeopithecus*) have a fold of skin extending along each side of the neck and body and continued between the hind-legs, enclosing the tail; the fore- and hind-feet are both webbed, and the tail is prehensile. The hedgehog (*Erinaceus*) has the surface beset with pointed spines. The moles (*Talpa*) and their allies, which are active burrowers, have the limbs very short and stout and provided with extremely strong claws. The jumping shrews (*Macroscelididæ*) have slender limbs adapted to progressing by leaps on the surface of the ground.

The Chiroptera (Fig. 327) are the only mammals which are capable of active flight. The fore-limbs have the segments greatly elongated, especially the fore-arm and the four ulnar digits, and these support a thin fold of the integument which stretches to the hind-limbs and constitutes the wing. A fold also extends between the hind-limbs and may or may not involve the tail. The pollex is much shorter than the other digits, directed forwards, and terminates in a well-developed curved claw; in the Megachiroptera, but not in the Microchiroptera, the second digit also has a claw; the other digits are always clawless. The position of the hind-limbs is peculiar, and the knee is directed backwards instead

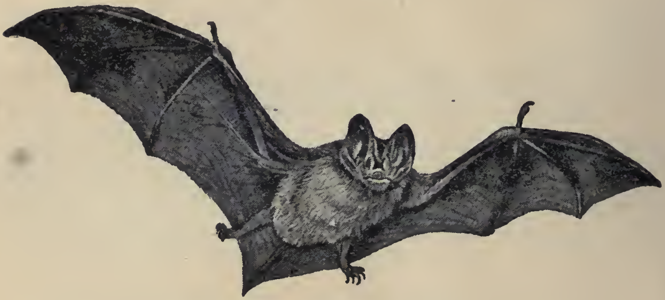

FIG. 327.—**Bat** (*Synotus barbastellus*). (After Vogt and Specht.)

of forwards as in other mammals; the five digits of the foot are all provided with claws. So complete is the adaptation of the limbs to the purpose of flight that bats are only able to shuffle along with great difficulty on the ground, though with the aid of their claws they are able to climb and to suspend themselves from branches of trees by the hind-feet.

In the lemurs and their allies (*Prosimii*) the body is slender, and the limbs adapted for an arboreal existence. The hallux is divergent from the other digits of the foot and opposable to them, and the same holds good, in some cases, of the pollex. In some, all the digits are provided with claws, or all but the hallux. More commonly all the digits are provided with flat nails, except the second of the pes, which always has a claw. The eyes are very large. The muzzle is sometimes elongated, sometimes short; the nostrils are slit-like. The tail is sometimes absent or short; more usually it is greatly elongated, but it is never prehensile. The surface is always covered with soft fur.

Of the remaining groups of Primates the Hapilidæ or marmosets are small squirrel-like animals with all the digits except the hallux provided with pointed claws, with the pollex incapable of opposition, the tail non-prehensile, and without cheek-pouches or callous patches over the ischia. The Cebidæ, or American monkeys, resemble the Hapalidæ in the negative characters of the absence of ischial callosities and of cheek-pouches, and of the power of opposition in the hallux. But the limbs are much longer, the digits are all provided with flat nails, and the tail is frequently prehensile. The Cercopithecidæ, or baboons and macaques, all have brightly coloured bare callous patches of skin (callosities) over the ischia, and most of them have cheek-pouches for the storage of food. All the digits are provided with flat nails. The tail may be long or short or absent; when present it is never prehensile. The pollex when developed is always opposable to the other digits. In the Simiidæ or man-like apes, a tail is never developed, and there are no cheek-pouches; ischial callosities are only present in the gibbons. The gibbons can walk in an upright position without the assistance of the fore-limbs; in the others, though in progression on the surface of the ground, the body may be held in a semi-erect position with the weight resting on the hind-limbs, yet the assistance of the long fore-limbs acting as crutches is necessary to enable the animal to swing itself along.

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